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# THE ONTARIO ASSESSMENT INSTRUMENT POOL

# CHEMISTRY IV

## SENIOR DIVISION

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# CHEMISTRY IV
# SENIOR DIVISION
# ONTARIO ASSESSMENT INSTRUMENT POOL

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## Chapter 14

## LABORATORY INSTRUMENTS

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## INSTRUCTIONS FOR USE OF LABORATORY INSTRUMENTS

The laboratory instruments were designed to be used in many diverse ways at the discretion of the teacher.

Some suggestions are:

1) Introduction of new topics
2) Review of topics previously taught
3) Mid-term (Formative Evaluaton) tests
4) End of term (Summative Evaluation) tests

The essential idea is that students be given the opportunity to DESIGN and think about their laboratory work and that teachers teach towards this end.

If the teacher wishes to use any of these instruments for testing purposes it is essential that the students be aware of the testing procedures.

If the students are not familiar with the procedures involved in this type of testing give them a number of practice sessions - working either singly or in pairs - prior to the test day. The students might also be given a printed example of a completed problem. The copies should be collected before the students leave the class.

Two "models" have been developed for the laboratory instruments.

1) PROCEDURAL STEP MODEL

   In this model the student may ask for or be given specific PROCEDURAL STEPS to be used in the laboratory. The student is required to design additional PROCEDURAL STEPS to complete the problem.

2) CLUE MODEL

   This model allows for a greater degree of student inquiry and inventiveness. The student may ask for or be given a series of CLUES which he uses to aid in the design of a laboratory procedure to solve the problem at hand. The CLUES are NOT steps in a laboratory precedure.

The laboratory instruments, both CLUE MODEL and PROCEDURAL STEP MODEL are found in CHAPTER XIV of this pool.

Each of the laboratory problems is written with the same general layout. Each of the instruments consists of a "Student Problem Sheet" and a "Teacher's Guide Sheet". In the outline which follows the problem layout is printed in regular (Titan 10) type and the editorial comments in Gothic 12 type.

## General Outline of Laboratory Instruments

### I INTRODUCTION

In this section the student is introduced to the subject matter to be evaluated. In some of the problems the student will be directed to perform a preliminary experimental operation on which he will be tested in the actual problem.

### II SPECIAL LAB KIT

The hardware, glassware and chemicals specific to this problem are listed. The list may include materials that are not necessary. The teacher must decide whether or not to include those materials to act as distractors. The teacher must also decide if the SPECIAL LAB KIT is to include sufficient materials to answer the problem in a variety of ways or to restrict the problem to only one solution. Materials that are included in the "Standard Laboratory Equipment" are not necessarily listed under the SPECIAL LAB KIT.

### III PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to.. The specific problem is outlined in this section; for some problems a few lines may precede the "Using only...experiment to...

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

The teacher must check the DESIGN in order to be certain that no unsafe procedures are being attempted. The DESIGN section must also be evaluated (Section A) before the student proceeds to work either with or without any or all of the PROCEDURAL STEPS/CLUES.

## IV ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

Students are encouraged to write an Alternate Solution. This provides an avenue for students who wish to expand the solution they have written, or to supply a solution entirely different from those that the problem designers predicted. The Alternate Solutions(s) may require any form of equipment or supplies - no matter how exotic or sophisticated. Through this section the problems are made as open-ended as possible.

Individual teachers may choose to supply the materials necessary for an Alternate Solution and allow the student to perform the procedures that they have personally designed.

Individual teachers can decide how to use the score assigned to this secton - either as part of the mark out of 25 (a bonus) or to increase the possible total mark to 30 or more.

## V TIMING

(1) Time allowed for the complete problem 40 minutes
(2) Time allowed for the "experimental design" 15 minutes

The time allotment given here follows FORMAT A; the times are flexible. Many teachers have increased the time allowed to 50-75 minutes, depending on the length of the class period. Any convenient time distribtution is appropriate. Formats B, C, D and E are described in the GENERAL INSTRUCTIONS TO THE TEACHER. A variety of FORMATS are possible and encouraged.

The 15 minute design and design evaluation period (FORMAT A) is only viable in a very small group - no more than 8 students. For large groups FORMATS B, C, D and E are more convenient and workable.

## VI TEST FORMAT

### A) PROCEDURAL STEP MODEL

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate

STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

Students are advised to ask for PROCEDURAL STEPS as soon as they think that they are "stuck". There is ample opportunity provided to recover Design marks.

After 15 minutes the students' designs will be collected and evaluated. Students will be given complete procedures to follow unless they have presented procedures which have been evaluated as complete and workable.

Only in FORMATS A and B may students request the "next" procedural step while designing the experiment. Procedures must be complete before laboratory work is started. In FORMATS C, D and E the students are given all the procedural steps they require during evaluation of the Design. In each case the teacher decides which procedural step(s) to give to each of the student.

B) CLUE MODEL

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are ___ CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No___) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 minutes the student will be given a CLUE if the Design presented by the student is not sufficient to allow the student to start performing laboratory work.

Only in FORMATS A and B may students request the CLUES while designing the experiment. Procedures must be approved before laboratory work is started. In FORMATS C, D and E the students are given all the CLUES they require during evaluation of the Design. In each case the teacher decides which CLUES to give the student.

The teacher may suggest that laboratory work be started before the procedure is complete. A student may develop further steps in the procedure after making some initial observations.

In both the CLUE MODEL and the PROCEDURAL STEP MODEL the students exhibit inertia towards accepting assistance. They must, by experience, learn that some marks must be sacrificed in order to conserve time. This stage in the learning process is a difficult, but important stage for the students to internalize.

## VII EVALUATION SCHEME

NOTE: (1) You are permitted to use the Handbook of Chemistry and Physics (Chemical Rubber Publishing Co.) as well as your textbook.

(2) You must leave ALL your "rough work" with the teacher.

The Handbook of Chemistry and Physics is not available in all schools. Some teachers prefer a data book or a data sheet which may be provided to the students. Any variation is acceptable. The idea here is to teach students to use reference materials such as the Handbook. Individual teachers may elect to allow students to take notebooks into the test. The option is open.

A useful and inexpensive alternative to the Handbook of Chemistry and Physics is:
Handy Chemical Data for Student (SI Metric)
(The Science Teachers' Association of Ontario #79004)

### A) PROCEDURAL STEP MODEL

(Total possible score......25)

| DESIGN (15 marks) | | | PERFORMANCE (10 marks) |
|---|---|---|---|
| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) | |
| 1. ____ | 1. ____ | 1. ____ | The awarding of performance marks will vary with each problem. |
| 2. ____ | 2. ____ | 2. ____ | |
| 3. ____ | 3. ____ | 3. ____ | |
| 4. ____ | 4. ____ | 4. ____ | |
| 5. ____ | 5. ____ | 5. ____ | |

Each of the five PROCEDURAL STEPS is assigned 3 marks during Phase I of the DESIGN period.

After the initial evaluation the student is given the next procedural step - this step will depend on the student's progress.

In Phase II of the DESIGN period the student is awarded 2 marks for each additional procedural step that he designs.

A very simple matrix can be developed to illustrate the mark assignment - see page 83.

The student need only design one of the procedural steps (in Phase I) in order to be eligible to score 13/25 on any problem.

B) CLUE MODEL (Total possible score....25)

| DESIGN (5 marks) | |
|---|---|
| NONE | 0 |
| FAULTY (requires an initial clue) | 2 |
| FAULTY (does not require an initial clue) | 3 |
| GOOD AND WORKABLE | 5 |

CLUES (9 marks)

No. 1 ___ 2
No. 2 ___ 1
No. 3 ___ 2
. .
. .
. .
. .
. .
No. n-1
No. n ___ 9

PERFORMANCE (11 marks)

The awarding of performance marks will vary with each problem.

Each of the n-1 CLUES is assigned a number of marks which total to 8. The CLUES are not necessarily of equal value. The nth clue (the Procedural Clue) is assigned a value of 9 marks.

The student can obtain a score of 13/25 if he makes any attempt at an initial Design - however faulty.

In both the PROCEDURAL STEP MODEL and the CLUE MODEL the student can score 13/25 if he does minimal design and then follows a given procedure accurately and carefully.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII PROCEDURAL STEPS/CLUES

A teacher must be present in the laboratory whenever there are any students working. The teacher must be available to provide CLUES/PROCEDURAL STEPS to the students so that time is not wasted.

The delivery of CLUES/PROCEDURAL STEPS is different, depending on the format being used. The formats differ in the time allowed for design. The formats are described beginning on page 72.

### A) PROCEDURAL STEPS

The procedure for each problem is divided into five approximately equal parts. The steps are clearly stated procedural directions for the student to follow. After receiving a step or steps, the student (Formats A and B) may continue to design the remainder of the experimental procedure. The procedural steps are provided for the teacher to duplicate, cut up and distribute as necessary. The teacher should plan to retrieve all of the steps by stapling them to the student's Scoring Guide as the steps are distributed.

### B) CLUES

For each problem there are a number of CLUES, including the last CLUE - the Procedural Clue. The clues are hints which may assist the student to complete an experimental design. After receiving a clue or clues, the student (Formats A and B) may continue to design additional stages in the experimental procedure. The clues are provided for the teacher to duplicate, cut and distribute as necessary. The teacher should plan to retrieve all of the CLUES by stapling them to the student's Scoring Guide as the CLUES are distributed.

## IX SUGGESTED PROCEDURE

There are many procedures for solving each of the problems. The set of CLUES/PROCEDURAL STEPS is designed to lead the students to the procedure outlined in the TEACHER'S GUIDE section VIII. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

There may be many procedures for solving each of the problems. The outline in this section is only one possible procedure that students might suggest. The teacher is responsible for approving any procedure(s) that might be suggested.

In most cases only one solution has been provided. The solution is outlined in detail with the five procedural step divisions indicated. This complete outline also corresponds to the Procedural Clue. Teachers are encouraged to outline additional procedures in this section as they and their students devise new methods of solving the problem in question.

## X SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for all of the problems. In this section the teacher is also provided with data, recipes and suggestions for use with each of the specific problems.

## SCORING GUIDE

The following two sheets (both sides) are samples of the PROCEDURAL STEP MODEL and CLUE MODEL SCORING GUIDES for a typical problem. All of the evaluation information required by the teacher is included on the two sides of the sheet.

## STANDARD LABORATORY AND SECURITY ARRANGEMENTS

1. Provide sufficient test tubes, glassware and distilled water so that students can use and rinse equipment readily.
2. Provide all standard laboratory apparatus such as beakers, clamps, burners, tongs, etc.
3. Make safety glasses available and mandatory for those students who do not ordinarily wear eye glasses.
4. Please collect ALL materials with which each student was working - both written as well as chemical.
5. Do not allow the students to take any "rough notes" out of the laboratory.
6. Space the students in the laboratory to ensure individual work.
7. Make a copy of "The Handbook of Chemistry and Physics" available to the students.
8. Make copies of the Periodic Table available to the students.
9. Ask student NOT to write on the question papers.
10. Be sure to collect all copies of the CLUES/PROCEDURAL STEPS.
11. Make sure that students return items to the SPECIAL LAB KIT.
12. Label the trays containing UNKNOWNS so that you can cross-reference the Tray Number and the Unknown Codes.
13. For problems in which unknowns are used the coding system must be varied regularly in order to ensure individual student work. The individual teachers will assign the appropriate code letters to the unknowns.

## STANDARD LABORATORY EQUIPMENT

All of the materials in the following list may not be necessary for all of the laboratory problems. Teachers may substitute or omit some of the items. The list is provided to allow students to select some materials at their own option.

These materials are to be provided in addition to the SPECIAL LAB KIT. Some of the materials in this list may also appear in the SPECIAL LAB KIT for individual problems.

1. Test tubes (variety of sizes)
2. Glass plates or spot plates (black, white and clear)
3. Beakers (50, 100, 250, 400 and 600 mL)
4. Flasks (Erlenmeyer - 250 mL)
5. Funnels
6. Evaporating dishes
7. Eye droppers
8. Pipets
9. Stirring rods
10. Clamps - test tube and ring
11. Bunsen burner
12. Gauze mat
13. Matches
14. Glass cutting files
15. Glass tubing
16. Tongs
17. Rubber stoppers - variety of sizes
18. Buret
19. Balance (centigram)
20. Stop watch (if available)
21. Crucibles and covers
22. Thermometer (-10 to 110 degrees °C)
23. Filter paper
24. Wood splints
25. Litmus paper (red and blue)
26. Distilled water (in dispenser bottle)
27. Delivery tubes
28. Graduated cylinders (10, 25, 50, 100 and 250 mL)
29. Gas collecting bottles
30. Cover glasses
31. Support stand
32. Wax pencil

NOTE 1. Additional materials may be specified for individual problems - some will be supplied along with the printed materials.

2. If any of these materials are not available, individual teachers may choose to make substitutions or additions.

## GENERAL INSTRUCTIONS - TO THE TEACHER

### FORMAT A

Students are presented with a problem and allowed one class period to complete the problem. The first 15 minutes of the period are assigned to EXPERIMENTAL DESIGN; the remainder of the period is used for actual experimental work. The time distribution can be varied by individual teachers.

### SPECIAL CONSIDERATIONS - FORMAT A

1. There should be no more that 8 students in the laboratory. This will allow the teacher the opportunity to move about the laboratory and supervise all the students.
2. Ideally the students should not be working on the same problem.
3. The problems should be distributed around the laboratory.
4. During the initial 15 minute Design Period the teacher must evaluate all the student designs.
5. CLUES/PROCEDURAL STEPS are given to students who request the CLUES/PROCEDURAL STEPS as well as (at the discretion of the teacher) to those students who appear to be "stuck".
6. At the end of the Design Period (15 minutes) the students must be given those CLUES/PROCEDURAL STEPS necessary to complete their procedures.
7. Students must write their suggested procedure in detail on the Scoring Guide.
8. Marks are entered on the Scoring Guide while the students are working.

NOTE:

i) The 15 minute DESIGN Period is rushed; the teacher may find it difficult to evaluate all 8 Designs during the 15 minute period.

ii) The restriction to a maximum of 8 students at a time is flexible. The number can be maximized by making use of time before and after classes, lunch hours and free periods.

iii) For evaluation use the laboratory instruments can be administered during the regular examination timetable. Students can "sign up" for specific time periods.

## FORMAT B

Students are presented with a problem and allowed two class periods, or parts thereof, to complete the problem. The teacher must decide how much time should be devoted to each aspect of the problem.

On day 1 the students may be given between 15 minutes and the full period (at the discretion of the individual teacher) to complete the EXPERIMENTAL DESIGN. During this time the teacher may be asked for CLUES/PROCEDURAL STEPS by individual students. The teacher should not offer CLUES/PROCEDURAL STEPS to student(s) unless called upon by the student(s).

At the end of the Design Period the Scoring Guides, problems and SPECIAL LAB KITS are collected from each student.

## SPECIAL CONSIDERATIONS - FORMAT B

1. All students can work at the same time.
2. All students can work on the same problem, or on one of two different problems. Students sitting at the same lab bench should be given different problems.
3. The teacher is not obligated to evaluate a large number of Designs in a short period of time.
4. The EXPERIMENTAL DESIGNS are evaluated by the teacher after the class period.
5. CLUES/PROCEDURAL STEPS are stapled to the students' Scoring Guides. Since the students are free to discuss the problem with classmates, and others, it is not possible to continue the Design feature of the test on the second day. Each student should be given all the CLUES/PROCEDURAL STEPS necessary in order to complete his design. Students are encouraged to perform the experiment which they designed.
6. Indicate on the Scoring Guide those CLUES/PROCEDURAL STEPS that were necessary for the student to complete the problem. In the case of the CLUE MODEL the teacher will have to decide whether or not a particular student actually required the Procedural Clue.
7. The second day becomes a lab day - all students should work independently.
8. The unknowns must be coded - and coded differently for each student. This will prevent copying of data.
9. In those cases where there are a variety of unknowns available, code and spread the different unknowns around the laboratory.

NOTE:
- i) Any out-of-school discussion will not change the DESIGN marks. The DESIGNS are evaluated on work done in class on day 1. The out-of-school discussions can only be advantageous.
- ii) Additional CLUES or PROCEDURAL STEPS may be necessary for some students on day 2.

## FORMAT C

FORMAT C is identical to FORMAT B in all but one respect. The teacher evaluates each student's procedure, then provides each member of the class with a complete procedure to follow. All students perform the same experiment. In essence, day 1 is a Design period and day 2 is a laboratory period. At the teacher's discretion, depending on the length of time of available, both the Design and the laboratory work can be done in the same class period.

## SPECIAL CONSIDERATIONS - FORMAT C

1. PROCEDURAL STEPS/CLUES that the student required should be stapled to the student's DESIGN so that he knows how well he did on the DESIGN part of the evaluation.

2. The teacher only has to prepare materials for one laboratory procedure. Considerable time is saved for the teacher by using FORMAT C.

3. It is possible that some students may feel "cheated" by not performing the experiment they designed.

4. The students must know, beforehand, what general format the test will follow. They should not be surprised that they will all perform the same experiment.

## FORMAT D

FORMAT D is identical to FORMAT B in all except one respect. No CLUES/ PROCEDURAL STEPS are distributed during the Design Period. At the end of the Design Period all materials are collected by the teacher.

## SPECIAL CONSIDERATIONS - FORMAT D

1. The problems are used in a two day format. Day 1 is a Design Period. Day 2 is a laboratory period.

2. Laboratory Designs are evaluated out of class by the teacher.

3. The teacher staples to the students' Scoring Guide the CLUES/PROCEDURAL STEPS necessary to complete the experimental procedure. In the case of the CLUE MODEL the teacher will have to decide whether or not a particular student actually required the Procedural Clue.

4. On the second day each student performs the experiment he has designed, or the experiment that he was given if the student design was not workable.

## FORMAT E

FORMAT E is identical to FORMAT C in all except one respect. No CLUES/PROCEDURAL STEPS are distributed during the Design Period. At the end of the Design Period all materials are collected by the teacher.

## SPECIAL CONSIDERATIONS - FORMAT E

1. The problems are used in a two day format. Day 1 is a Design Period. Day 2 is a laboratory period.
2. Laboratory Designs are evaluated out of class by the teacher.
3. The teacher staples to the student's Scoring Guide the CLUES/PROCEDURAL STEPS necessary to complete the experimental procedure. In the case of the CLUE MODEL the teacher will have to decide whether or not a particular student actually required the Procedural Clue.
4. On the second day the teacher distributes the same experimental procedure to all the students. The students all perform the same experiment - the experiment outlined in the procedural clue.
5. The teacher may decide to complete the whole exercise in one class period. After collecting the student designs, distribute the experiment outline to the students.

## GENERAL INSTRUCTIONS TO THE STUDENT

### FORMAT A

1. Do NOT start any experimental work until approval is received from the teacher.

   No Experimental work is to be done until your Experimental Design is complete and approved by the teacher.

2. All Experimental Designs MUST be written in detail in Section A of the Scoring Guide. Call the teacher to your work area when you have completed your initial Laboratory Design. The procedure must include outlines of all the calculations (if necessary) that will be performed.
3. There are some problems for which some special experimental work is done prior to the Experimental Design. The instructions for the problem will indicate this clearly. The teacher will tell you which experiment(s) to perform.

4. Do NOT taste any materials - some may be poisonous.

5. For each problem you may be provided with a data sheet as well as all the necessary equipment and supplies. For each problem there is a SPECIAL LAB KIT in addition to a kit of Standard Laboratory apparatus.

6. You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any materials provided by the teacher.

7. Each problem is assigned an initial 15 minute Design Period. Following that time period the teacher will evaluate your progress and give you the PROCEDURAL STEPS/CLUES necessary to complete the procedure that you have designed.

8. You will get significant credit for any design that you produce during the initial Design Period. There are many possible correct designs for each problem.

9. The category titled "Alternate Solution(s)" will enable you to suggest solutions that were not provided for in the SPECIAL LAB KIT. You will receive additional credit for these solutions. There may be many alternate solutions for each problem.

10. Remember that these materials have been used by other people. Rinse all glassware and transferring equipment with distilled water before you use the equipment.

11. You may NOT remove any written, printed or laboratory materials from the laboratory.

12. Please replace the SPECIAL LAB KIT in the form in which you found it.

A) PROCEDURAL STEP MODEL

Do NOT waste time - if you do not know how to proceed - ask for a PROCEDURAL STEP. You may request a series of PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in sequential order. The teacher - after examining your progress will give you the appropriate PROCEDURAL STEP(S). Each PROCEDURAL STEP that you are given will result in a lower possible score that you may achieve. Fifteen (15) marks out of 25 are reserved for PROCEDURAL STEPS. It is advisable that you request a PROCEDURAL STEP as soon as you are "stuck". This will avoid waste of time during the Design Period.

Ten (10) marks out of the 25 marks are reserved for performance of the experiment and a correct solution to the problem. Even if your require four of the five PROCEDURAL STEPS you can still score 13/25 on each of the problems.

B) CLUE MODEL

Do NOT waste time - if you do not know how to proceed - ask for a CLUE. You may request a series of CLUES from the teacher. The CLUES are arranged in sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you are given will result in a lower possible score that you may achieve. Nine (9) marks out of 25 are reserved for CLUES. The final CLUE for each problem (Procedural Clue) outlines one possible procedure for the solution to the problem. The use of this final CLUE will result in the loss of all nine (9) marks reserved for the CLUES. It is always advisable that you take some of the earlier CLUES before requesting the Procedural Clue for any problem. It is advisable that you request a CLUE as soon as you are stuck. This will avoid waste of time during the Design Period.

Eleven (11) marks out of the 25 marks are reserved for performance of the experiment and a correct solution to the problem. Even if you require all the CLUES, following an initial design attempt, you can still score 13/25 on each of the problems.

## FORMAT B

FORMAT B is similar to FORMAT A, with the following exceptions.

1. The problem assigned to you must be completed in two stages - on separate days.

2. On the first day you will be given the problem and will have a specified time period to design a laboratory solution to the problem. On the second day you will use your method (corrected by the teacher, if necessary) to actually determine an answer to the problem you were given.

## FORMAT C

FORMAT C is similar to FORMAT A and FORMAT B, with the following exceptions.

1. The problem assigned to you must be completed in two stages - on separate days, or if indicated by the teacher,on the same day.

2. On the first day you will be given the problem and will have a specified time period to design a laboratory solution to the problem. On the second day you will use your method (corrected by the teacher, if necessary) to actually determine an answer to the problem you were given. All students will perform the same experiment.

FORMAT D

FORMAT D is similar to FORMAT B, with one major exception.

You will NOT receive any PROCEDURAL STEPS/CLUES on day 1 during the Design Period.

1. The problem assigned to you must be completed in two stages - on separate days.

2. On the first day you will be given the problem and will have a specified time period to design a laboratory solution to the problem. On the second day you will use your method (corrected by the teacher, if necessary) to actually determine an answer to the problem you were given.

3. On the second day the teacher will return your Scoring Guide and will allow you to perform the experiment that you designed, or the experiment outlined in the PROCEDURAL STEPS/CLUES that are stapled to your Scoring Guide.

FORMAT E

FORMAT E is similar to FORMAT C with one major exception.

1. You will NOT receive any PROCEDURAL STEPS/CLUES during the Design Period.

2. The problem assigned to you must be completed in two stages - on separate days.

3. On the first day you will be given the problem and will have a specified time period to design a laboratory solution to the problem. On the second day you will use your method (corrected by the teacher, if necessary) to actually determine an answer to the problem you were given.

4. On the second day the teacher will return your Scoring Guide and will allow you to perform the experiment that you designed, or the experiment outlined in the PROCEDURAL STEPS/CLUES that are stapled to your Scoring Guide.

## Summary of FORMATS A, B, C, D and E.

### TO THE TEACHER

### FORMAT A

One full class period is required. The period may be 35 to 70 minutes in length.

The Design and the Laboratory work are done in the same period. The Design work is done in the first 15 to 30 minutes and the Laboratory work in the remaining 25 to 55 minutes. The length and distribution of time is at the discretion of the teacher.

The small number (6 - 10) of students allows for student - teacher interactions. The students can recover Design marks after receiving one or more PROCEDURAL STEPS/CLUES.

### FORMAT B

Parts of two class periods are required. Design is done on Day 1, at the end of the period (15 - 30 minutes). Laboratory work is done on Day 2 (25 - 70 minutes).

The opportunity for recovery of Design marks is more limited because the larger number (full class) of students limits the student - teacher interactions during the Design Period. Students perform their own Experiment on Day 2.

### FORMAT C

Parts of two class periods are required. Design is done on Day 1, at the end of the period (15 - 30 minutes). Laboratory work is done on Day 1 or Day 2 (25 - 70 minutes).

The opportunity for recovery of Design marks is more limited because the larger number (full class) of students limits the student - teacher interactions during the Design Period. Students all perform the same experiment, designed by the teacher, on Day 1 or Day 2.

### FORMAT D

Parts of two class periods are required. Design is done on Day 1, at the end of the period (15 - 30 minutes). Laboratory work is done on Day 2 (25 - 70 minutes).

The opportunity for recovery of Design marks is NOT available. No PROCEDURAL STEPS/CLUES are distributed during the Design Period.

All evaluation is carried out after the Design Period is concluded.

Students perform their own experiments on Day 2.

### FORMAT E

Parts of two class periods are required. Design is done on Day 1, at the end of the period (15 -30 minutes). Laboratory work is done on Day 1 or Day 2 (25 - 70 minutes).

The opportunity for recovery of Design marks is NOT available.

No PROCEDURAL STEPS/CLUES are distributed during the Design Period.

All evaluation is carried out after the Design Period is concluded.

Students all perform the same experiment, designed by the teacher on Day 1 or Day 2.

## EVALUATION PATTERN

## PROCEDURAL STEP MODEL
## FORMAT A,B,C

### EXPERIMENTAL DESIGN (Maximum 15 Marks)

(a) The student is assigned marks (to a maximum of 15 marks) for each of the PROCEDURAL STEPS that are designed correctly.
(b) The student is awarded 3 marks for each of the PROCEDURAL STEPS that are designed correctly, prior to the initial, Phase I evaluation of the Experimental Design by the teacher.
(c) The student is awarded 2 marks for each of the PROCEDURAL STEPS that are designed correctly, after the initial, Phase II evaluation of the Experimental Design by the teacher.
(d) There are NO penalties assessed for requesting and receiving one or more PROCEDURAL STEPS.

### ASSIGNMENT OF MARKS

During the Initial Design Period (Phase I) the student may design any or all of the PROCEDURAL STEPS ($P_1$, $P_2$, $P_3$, $P_4$ and $P_5$) corectly. The student is awarded 3 marks for each of the STEPS designed correctly.

The PATTERN of marks awarded for correct Design is outlined in the following sections.

1) Complete Design (Phase I)
   5/5 All five STEPS are designed correctly during the Initial Design Period. 15

2) Incomplete Design (Phase I)
   4/5 Four of the five STEPS are designed correctly during the Initial Design Period. The student is given $P_5$. 12

3) Incomplete Design (Phase I)
   3/5 Three of the five STEPS are designed correctly during the Initial Design Period. The student is given $P_4$.
      (i) The student designs $P_5$ correctly 11
      (ii) The student is given $P_5$. 9

4) Incomplete Design (Phase I)

   2/5 Two of the five STEPS are designed correctly during the Initial Design Period. The student is given $P_3$.
      (i) The student designs $P_4$ and $P_5$ correctly. 10
      (ii) The student designs 1 of $P_4$ and $P_5$ correctly and is given the remaining PROCEDURAL STEP. 8
      (iii) The student is given $P_4$ and $P_5$. 6

5) Incomplete Design (Phase I)

1/5 One of the five STEPS is designed correctly during the Initial Design Period. The student is given $P_2$.

- (i) The student designs $P_3$, $P_4$ and $P_5$ correctly. 9
- (ii) The student designs 2 of $P_3$, $P_4$ and $P_5$ correctly and is given the remaining PROCEDURAL STEP. 7
- (iii) The student designs 1 of $P_3$, $P_4$ and $P_5$ correctly and is given the two remaining PROCEDURAL STEPS. 5
- (iv) The student is given $P_3$, $P_4$ and $P_5$. 3

6) Incomplete Design (Phase I)

0/5 None of the five STEPS are designed correctly during the Initial Design Period. The student is given $P_1$.

- (i) The student designs $P_2$, $P_3$, $P_4$ and $P_5$ correctly. 8
- (ii) The student designs 3 of $P_2$, $P_3$, $P_4$ and $P_5$ correctly and is given the remaining PROCEDURAL STEP. 6
- (iii) The student designs 2 of $P_2$, $P_3$, $P_4$ and $P_5$ correctly and is given the two remaining PROCEDURAL STEPS. 4
- (iv) The student designs 1 of $P_2$, $P_3$, $P_4$ and $P_5$ correctly and is given the three remaining PROCEDURAL STEPS. 2
- (v) The student is given $P_2$, $P_3$, $P_4$ and $P_5$. 0

## PERFORMANCE (Maximum 10 marks)

The various STEPS in the procedure, calculations and the answer to each problem will be assigned credit that total 10 marks. The student may obtain all or any of these 10 marks regardless of the number of PROCEDURAL STEPS given to the student.

Examination of the EVALUATION PATTERN indicates that in order to achieve a score of 13/25 the student must produce some of the Experimental Design.

## EVALUATON PATTERN

### PROCEDURAL STEP MODEL
### FORMAT D, E.

### EXPERIMENTAL DESIGN (Maximum 15 marks)

(a) The student is assigned marks (to a maximum of 15) for each of the PROCEDURAL STEPS that are designed correctly.

(b) The student is awarded 3 marks for each of the PROCEDURAL STEPS that are designed prior to evaluation of the Experimental Design by the teacher (Phase I).

(c) There are NO penalties assessed for requesting and receiving one or more PROCEDURAL STEPS.

### ASSIGNMENT OF MARKS

During the Design period the student may design any or all of the PROCEDURAL STEPS ($P_1$, $P_2$, $P_3$, $P_4$ and $P_5$) correctly. The student is awarded 3 marks for each of the PROCEDURAL STEPS designed correctly.

### PERFORMANCE (Maximum of 10 marks)

The various steps in the calculations and the answer to each problem will be assigned credit that total 10 marks. The student may obtain all or any of these 10 marks regardless of the number of PROCEDURAL STEPS given to the student.

Examination of the EVALUATION PATTERN indicates that in order to achieve a score of 13/25 the student must produce some of the Experimental Design.

## MATRIX OF MARKS

| | PHASE I INITIAL DESIGN No. Of STEPS | MARKS | No. of "FREE" STEPS GIVEN | PHASE II ADDITIONAL DESIGN No. of STEPS | MARKS | TOTAL MARKS |
|---|---|---|---|---|---|---|
| COMPLETE | | | | | | |
| 1) | 5 | 15 | 0 | 0 | 0 | 15 |
| INCOMPLETE | | | | | | |
| 2) | 4 | 12 | 1 | 0 | 0 | 12 |
| 3) (i) | 3 | 9 | 1 | 1 | 2 | 11 |
| (ii) | 3 | 9 | 2 | 0 | 0 | 9 |
| 4) (i) | 2 | 6 | 1 | 2 | 4 | 10 |
| (ii) | 2 | 6 | 2 | 1 | 2 | 8 |
| (iii) | 2 | 6 | 3 | 0 | 0 | 6 |
| 5) (i) | 1 | 3 | 1 | 3 | 6 | 9 |
| (ii) | 1 | 3 | 2 | 2 | 4 | 7 |
| (iii) | 1 | 3 | 3 | 1 | 2 | 5 |
| (iv) | 1 | 3 | 4 | 0 | 0 | 3 |
| 6) (i) | 0 | 0 | 1 | 4 | 8 | 8 |
| (ii) | 0 | 0 | 2 | 3 | 6 | 6 |
| (iii) | 0 | 0 | 3 | 2 | 4 | 4 |
| (iv) | 0 | 0 | 4 | 1 | 2 | 2 |
| (v) | 0 | 0 | 5 | 0 | 0 | 0 |

### EVALUATION PATTERN
### CLUE MODEL
### FORMAT A,B,C

EXPERIMENTAL DESIGN (Maximum 5 marks)

(a) The student does not prepare any laboratory design material within the Design Period. 0

5 (b) The student prepares a "faulty" laboratory design which in the opinion of the examiner does not contain a laboratory entry point. The student requires an "initial" CLUE prior to starting any laboratory work. 2

(c) The student prepares an incomplete laboratory design but does not need required an "initial" CLUE in order to start the laboratory work. 3

(d) The student prepares a good and workable laboratory design. 5

2. CLUES (maximum of 9 marks)

9 The student will gain nine (9) marks if he does not require any of the CLUES associated with the assigned problem. If the student requires the final CLUE (Procedural Clue) he will NOT be awarded any of the nine (9) marks associated with the CLUES. It is advisable that the student take some of the earlier CLUES before requesting the Procedural Clue.

3. PERFORMANCE (Maximum 11 marks)

The various steps in the procedure, calculations and the answer to each problem are assigned marks that total 11 marks. The student may obtain all or any of these 11 marks regardless of the number of CLUES required.

11 Examination of the EVALUATION PATTERN indicates that any student may obtain 13 marks out of the total possible score of 25 marks even if he requires all the available CLUES. It is only necessary that the student attempt to prepare a laboratory design in order to be able to obtain a score of 13/25 on each of the problems.

25
(TOTAL)

## CLUE MODEL FORMAT D, E.

The evaluation of sections:

I - Experimental Design (maximum 5 marks)

and III - Performance (maximum 11 marks)

are indentical to the evaluation pattern described for Formats A, B, and C.

II - CLUES (maximum 9 marks)

This section is evaluated in the same way as for Formats B and C, but the students are NOT given any clues during the Design Period. As a result of reading the Design, the teacher must decide which clues might have been given to each of the students.

In most cases, if the Design is not complete, the students will be judged to have required the Procedural Clue.

CHEMISTRY
SENIOR DIVISION
ONTARIO ASSESSMENT INSTRUMENT POOL

PACKAGE 4
Laboratory Instruments

CLUE
Model
PROBLEM NO.

TEMPLATE

## I. INTRODUCTION

## II. SPECIAL LAB KIT

## III. PROBLEM

Using only the materials in the Special Lab Kit design an experiment to............

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

| | |
|---|---|
| (1) Time allowed for the complete problem | 40 minutes |
| (2) Time allowed for the Experimental Design | 15 minutes |

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are   CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No.  ) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 minutes you will be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.....25)

| DESIGN (5 marks) | | CLUES (9 marks) | PERFORMANCE (11 marks) |
|---|---|---|---|
| NONE | 0 | No. 1 ___ | |
| FAULTY (requires an initial clue) | 2 | No. 2 ___ | |
| | | No. 3 ___ | |
| | | No. 4 ___ | |
| FAULTY (does not require an initial clue) | 3 | No. 5 ___ | |
| | | No. 6 ___ | |
| GOOD AND WORKABLE | 5 | No. 7 ___ | |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. CLUES

Clue No. 1
Clue No. 2
Clue No. 3
Clue No. 4
Clue No. 5
Clue No. 6
Procedural Clue (Clue No. 7)

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions
(a) (b) (c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.
(a) (b) (c)

**Procedural Step Model**

**PROBLEM NO.**

# TEMPLATE

## I. INTRODUCTION

## II. SPECIAL LAB KIT

## III. PROBLEM

Using only the materials in the Special Lab Kit design an experiment to.........

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated. You will be given a complete procedure to follow unless you have presented a procedure which has been evaluated as complete and workable.

## VII. EVALUATION SCHEME (Total possible score.......25)

| DESIGN (15 marks) | | PERFORMANCE (10 marks) |
|---|---|---|
| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) |
| 1. ____ | 1. ____ | 1. ____ |
| 2. ____ | 2. ____ | 2. ____ |
| 3. ____ | 3. ____ | 3. ____ |
| 4. ____ | 4. ____ | 4. ____ |
| 5. ____ | 5. ____ | 5. ____ |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. PROCEDURAL STEPS

PROCEDURAL STEP No. 1
PROCEDURAL STEP No. 2
PROCEDURAL STEP No. 3
PROCEDURAL STEP No. 4
PROCEDURAL STEP No. 5

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The teacher is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The teacher has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions
(a) (b) (c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.
(a) (b) (c)

# CLUE Model PROBLEM NO. 1

## I. INTRODUCTION

The chemist is frequently called upon to identify a series of "unknown" materials. On some of these occasions the materials and equipment available for use are limited.

## II. SPECIAL LAB KIT

Vials labelled respectively A, B, C, D and E.
Litmus paper (red and blue)
Light bulb assembly
Silver nitrate solution, $AgNO_3$, ($10^{-3}$ mol/L) in a dropper bottle
Hydrochloric acid, HCl, (1 mol/L) in a dropper bottle

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to correctly identify the contents of the five vials labelled A, B, C, D and E. Predict the observations that you would expect. Indicate how you would use these observations to identify the unknowns. The labels from five laboratory containers came off the containers and were mixed up. The labels, listed in alphabetical order are barium hydroxide, calcium carbonate, citric acid, sodium chloride and sugar. Individual samples of the five materials are contained in the vials labelled A, B, C, D and E.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 3 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 4) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you will be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.....25)

| DESIGN (5 marks) | | CLUES (9 marks) | | PERFORMANCE (11 marks) | |
|---|---|---|---|---|---|
| NONE | 0 | No. 1 ___ | 3 | 5 labels correct | 11 |
| FAULTY (requires an initial clue) | 2 | No. 2 ___ | 3 | 3 labels correct | 6 |
| | | No. 3 ___ | 2 | 2 labels correct | 4 |
| FAULTY (does not require an initial clue) | 3 | No. 4 ___ | 9 | 1 label correct | 2 |
| GOOD AND WORKABLE | 5 | | | 0 labels correct | 0 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. CLUES

### Clue No. 1

Substances can often be separated on the basis of their solubility in water.

### Clue No. 2

Litmus paper can be used to distinguish between aqueous (water) solutions of acids and bases.

### Clue No. 3

(a) The light bulb assembly can be used to compare the electrical conductivities of liquids.

or

(b) Silver nitrate ($AgNO_3$) will produce a precipitate with some solutions.

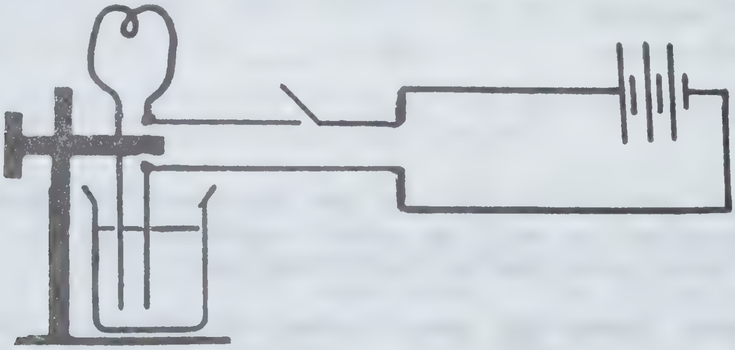
### Procedural Clue (Clue No. 4)

(a) Add a small sample of each solid to distilled water in individual test tubes.

(b) Determine the qualitative solubility (insolubility) of the solids in water. Only one of the solids is insoluble in water.

(c) Test the solutions with litmus paper. Red litmus turns blue in basic solution; blue litmus turns red in acidic solution.

(d) Use the light bulb assembly to distinguish between electrolytes and non-electrolytes. When the electrodes are immersed in an electrolyte the bulb will glow.



(e) Add a few drops of silver nitrate solution to the two remaining unknowns. A precipitate will form in one of the solutions.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a) To a small sample of each solid add the same volume of water. All of the solids will dissolve except the calcium carbonate. The student may verify the identity of the calcium carbonate by the addition of hydrochloric acid. It is not necessary that a confirmatory test be performed.

(b) Test the four solutions with litmus paper. The litmus paper will turn red in the citric acid, turn blue in the barium hydroxide solution and remain unchanged in the sodium chloride solution.

(c) Test the sodium chloride and sugar solutions for electrical conductivity. The conductivity will be greater in the sodium chloride solution.

The bulb will light in the sodium chloride solution if the concentration of the solution is at least 0.02 mol/L. If the concentration is less than 0.02 mol/L it may be possible to observe signs of electrolysis (gas formation).

or

(d) Silver nitrate solution will produce a white precipitate with sodium chloride solution, but not with sugar solution.

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Change the coding scheme for those candidates who are NOT in the laboratory at the same time. Students in the laboratory at the same time can have the same coding.

(b) The conductivity apparatus can be made with almost any metals. The bulb will "light" in very dilute (0.02 mol/L) electrolytes.

(c) The electrodes should NOT be shorted out. The bulb (1.5 volts or less) will "blow" easily. Have spare bulbs available.

(d) The dry cell is a nine (9) volt cell.

**CLUE Model PROBLEM NO. 1**

## Scoring Guide

Student ______

Date ______

Score ______

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________
7 ____________________
8. ____________________
9. ____________________

____________________

---

### For Teacher's Use Only

### Alternate Solution(s)

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution. ☐ 5

### Experimental Design (5 marks)

(Please check the appropriate level and enter mark in Space I)

| | |
|---|---|
| None | ______ 0 |
| Faulty (requires an initial CLUE) | ______ 2 |
| Faulty (does not require an initial CLUE) | ______ 3 |
| Good and Workable | ______ 5 |

### Clues (9 marks)

(Please check the **CLUES** that were given to the student. Enter the net marks obtained by the student for **CLUES** in Space II)

Net Mark = 9 - (CLUES used)

CLUE No. 1 ________

CLUE No. 2 ________

CLUE No. 3 ________

Procedural CLUE ________

### Performance (11 marks)

(Please enter the appropriate mark in Space III)

| | |
|---|---|
| 5 labels correct | 11 |
| 3 labels correct | 6 |
| 2 labels correct | 4 |
| 1 label correct | 2 |
| 0 labels correct | 0 |

**Experimental Design** ○ I

**Clues** ○ II

**Performance** ○ III

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# CLUE Model PROBLEM NO. 2

## I. INTRODUCTION

It is frequently necessary to remove an ion from a given solution This procedure can be performed in a variety of ways. The technique depends on the initial solution and the materials provided.

## II. SPECIAL LAB KIT

Dropper bottles containing 0.1 mol/l solutions of:
potassium chromate $K_2CrO_4$
nitric acid $HNO_3$
3 medicine droppers
10 mL graduated cylinder
ammonium nitrate $NH_4NO_3$
lead(II) nitrate $Pb(NO_3)_2$
Gummed labels
Spot plates (black and white)
Stoppered test tube labelled "for testing by the teacher"

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to

1) remove all the chromate ion, $CrO_4^{2-}$(aq), from 10 mL of potassium chromate, $K_2CrO_4$(aq), (0.1 mol/L) without introducing any excess of the species used to carry out the appropriate removal procedure.
2) verify that you have carried out the removal of chromate ion ($CrO_4^{2-}$(aq),completely, and also that there is no excess of the removing agent.
3) provide at least 6 mL of the resultant solution for the teacher to test.
4) As a preliminary step to developing your detailed design indicate to your teacher the reagent you will use to remove the chromate ion.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 4 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 5) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you will be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.....25)

| DESIGN (5 marks) | | CLUES (9 marks) | | PERFORMANCE (11 marks) | |
|---|---|---|---|---|---|
| NONE | 0 | No. 1 ___ | 2 | 1. Selected correct solution | 2 |
| FAULTY (requires an initial clue) | 2 | No. 2 ___ | 2 | 2. Calculated correct amount of solution | 2 |
| | | No. 3 ___ | 2 | 3. Provided at least 6 mL of solution | 3 |
| FAULTY (does not require an initial clue) | 3 | No. 4 ___ | 2 | 4. No excess of either ion in the solution | 4 |
| GOOD AND WORKABLE | 5 | No. 5 ___ | 9 | | |

The solution you have prepared must be placed in the test tube labelled "for testing by the teacher".

Make sure that the Problem No., Unknown No., and your name are on the label.

The teacher will test the solution for completeness of chromate ion removal.

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. CLUES

### Clue No. 1

Chromate ion, $CrO_4^{2-}(aq)$, can be removed from potassium chromate solution, solution $K_2CrO_4(aq)$, by precipitation to form an insoluble chromate.

### Clue No. 2

Write a balanced equation for the reaction that you might expect to occur. Determine the mole ratio of the chromate ion $(CrO^{2-})_4$ and the "removing ion".

### Clue No. 3

The number of moles of chromate ion in 10 mL of $K_2CrO_4$(0.1 mol/L) is $\frac{10}{1000} \times 0.1 = 0.001$ mol

Calculate the volume of the "removing ion" solution required to precipitate the chromate ion.

### Clue No. 4

To test for excess ions - filter the mixture, then test separate samples of the filtrate for the presence of chromate ion and for the presence of the "removing" ion.

### Procedural Clue (Clue No. 5)

(a) Pour potassium chromate solution to a depth of 1 cm into each of three test tubes.

(b) Add a few drops of the nitric acid solution, the lead(II) nitrate solution and the ammonium nitrate solution to each of the samples of the potassium chromate solution.

(c) Select the solution which may be used to remove the chromate ion by observing which of the added solutions caused a precipitate to form.

(d) The equation for the reaction of chromate ion and the "removing ion" must be written and balanced.

(e) The number of moles of chromate ion, $CrO_4^{2-}$ in 10 mL of the $K_2CrO_4$ solution is $\frac{10}{1000} \times 0.1 = 0.001$ mol.

(f) Since the precipitate is lead(II) chromate, $PbCrO_4$, the volume of lead(II) nitrate, $Pb(NO_3)_2$, solution can now be calculated.

(g) Add the appropriate volume of lead(II) nitrate, $Pb(NO_3)_2$, solution to the 10 mL of the potassium chromate, $K_2CrO_4$, solution.

(h) Filter the mixture.

(i) Test samples of the filtrate with each of potassium chromate and lead(II) nitrate solutions. If a precipitate forms in either case then one of the ions is still present.

(j) Pour the remaining filtrate into the labelled test tube for examination by the teacher.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Allow the students to perform the preliminary experimental work to identify the removing agent before they write their Design.

(b) The teacher's testing of the filtrates must allow for a measure of error. Test 2 mL of the filtrate with one drop of each of the test solutions.

(c) Change the identity of the "removing solutions" for different classes.

(d) Change the identity (concentration) of the known (potassium chromate) solution for different students and/or classes.

(e) Change the concentration of the "removing solution" for different students and/or classes.

NOTE If any of these changes are made then the CLUES and the content of the problem may have to be changed slightly.

**CLUE Model PROBLEM NO. 2**

**Scoring Guide**

Student ____________________

Date ____________________

Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________
7. ____________________
8. ____________________
9. ____________________

____________________

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### For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

**Experimental Design (5 marks)**

(Please check the appropriate level and enter mark in Space I)

| | |
|---|---|
| None | ____ 0 |
| Faulty (requires an initial CLUE) | ____ 2 |
| Faulty (does not require an initial CLUE) | ____ 3 |
| Good and Workable | ____ 5 |

**Clues (9 marks)**

(Please check the **CLUES** that were given to the student. Enter the net marks obtained by the student for **CLUES** in Space II)

Net Mark = 9 - (CLUES used)

| | |
|---|---|
| CLUE No. 1 | ____ |
| CLUE No. 2 | ____ |
| CLUE No. 3 | ____ |
| CLUE No. 4 | ____ |
| Procedural CLUE | ____ |

**Performance (11 marks)**

(Please enter the appropriate mark in Space III)

| | |
|---|---|
| Selected correct solution | 2 |
| Calculated correct amount of solution | 2 |
| Provided at least 6 mL of solution | 3 |
| No excess of either ion in the solution | 4 |

**Experimental Design** ○ I

**Clues** ○ II

**Performance** ○ III

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**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# CLUE Model PROBLEM NO. 3

NOTE - See Sections X(f) and X(g)

## I. INTRODUCTION

The chemist is frequently called upon to identify an unknown metal. On some of these occasions the materials and equipment available for use are limited. All of the initial observations indicate that the unknown metal is divalent.

## II. SPECIAL LAB KIT

Mass of metal in the gelatin capsule,____g.

bottle of hydrochloric acid solution, 6 mol/L
gelatin capsule containing powdered metal of known mass
thermometer
A barometer will be available in the laboratory.
100 mL graduated cylinder

## III. PROBLEM

You are provided with a capsule containing a known mass of a powdered metal. The metal is one of a) ________________,

b) ____________, c) ____________, d) ________________.

Using only the materials in the "SPECIAL LAB KIT" design an experiment to determine the identity of the metal. You will be given the mass of the metal in the gelatin capsule.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 5 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 6) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you will be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.....25)

| DESIGN (5 marks) | |
|---|---|
| NONE | 0 |
| FAULTY (requires an initial clue) | 2 |
| FAULTY (does not require an initial clue) | 3 |
| GOOD AND WORKABLE | 5 |

| CLUES (9 marks) | |
|---|---|
| No. 1 ___ | 2 |
| No. 2 ___ | 3 |
| No. 3 ___ | 1 |
| No. 4 ___ | 1 |
| No. 5 ___ | 1 |
| No. 6 ___ | 9 |

PERFORMANCE (11 marks)

1. Marks are awarded on the basis of the % error in the experimental data.

| Experimental Error | |
|---|---|
| >30% | 0 |
| 20-30% | 1 |
| 10-20% | 2 |
| <10% | 3 |

2. Calculations
   - a) Step 1____2
   - b) Step 2____1
   - c) Step 3____2

3. Identification of the metal.___3

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook as well as any materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

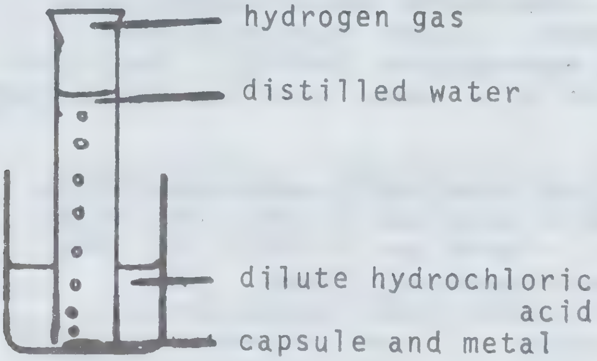
SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. CLUES

Clue No. 1

Metals react with acids to produce hydrogen gas.

Clue No. 2



Caution:

1. Invert the cylinder into water only; do not add acid to the water yet.
2. Be sure to cover the capsule with the ful graduated cylinder.
3. Add the acid after th cylinder is inverted the beaker of water.

Clue No. 3

One mole of hydrogen gas occupies 22.4 L at STP.

Clue No. 4

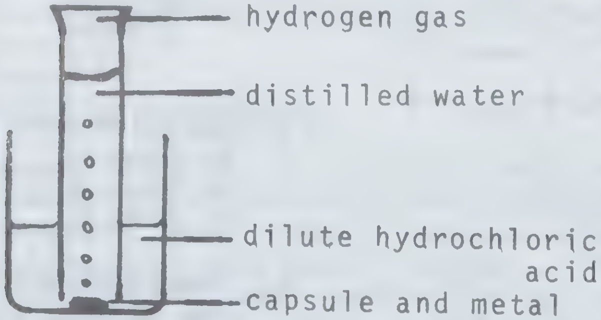
In this reaction the number of moles of metal consumed is equal to the number of moles of hydrogen gas produced.

Clue No. 5

$$\text{Atomic mass} = \frac{\text{Mass of metal in the capsule}}{\text{No. of mol of metal consumed}}$$

Procedural Clue (Clue No. 6)

1. Completely fill a graduated cylinder with distilled water and invert it over the capsule in a beaker containing 100 mL of distilled water.
2. Add 50 mL of 6 mol/L hydrochloric acid, HCl, to the water in the beaker.



1. Invert the cylinder into water only; do not add acid to the water yet.
2. Be sure to cover the capsule with the full graduated cylinder.
3. Add the acid after the cylinder is inverted in the beaker of water.

3. Allow the reaction to proceed until all the metal is consumed.
4. Measure the volume of hydrogen gas produced in the reaction.
5. Calculate the atomic mass of the metal using the number of moles of gas collected to calculate the number of moles of metal consumed.
6. $\text{Atomic mass} = \dfrac{\text{Mass of metal in the capsule}}{\text{No. of mol of metal consumed}}$

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) The metals that may be used are:

| | | | | |
|---|---|---|---|---|
| All of the metals are divalent. | Magnesium | (Mg - 24.2) | Nickel | (Ni - 58.7) |
| | Calcium | (Ca - 40.1) | Zinc | (Zn - 65.4) |
| | Chromium | (Cr - 52.0) | Cadmium | (Cd - 112.4) |
| | Iron | (Fe - 55.9) | Tin | (Sn - 118.7) |

$$M(s) + 2H^{+}(aq) \rightarrow M^{2+}(aq) + H_2(g)$$

(b) The metals and their masses have been chosen so that the corrections for STP and vapour pressure are unnecessary. The errors generated will be small.

(c) The mass of metal in the capsule should be selected so that approximately 100 mL of $H_2$ gas will be produced.

(d) In section III indicate to the students four (4) of the metals listed (one of them must be the correct answer).

(e) Select the four metals with significantly different atomic weights so that the student can readily get the correct

(f) Use this problem as an example for discussion purposes.

(g) Soluble gelatin capsules are difficult to obtain.

**CLUE Model PROBLEM NO. 3**

## Scoring Guide

Student ____________________

Date ____________________

Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ____________________ 6. ____________________
2. ____________________ 7. ____________________
3. ____________________ 8. ____________________
4. ____________________ 9. ____________________
5. ____________________ ____________________

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**For Teacher's Use Only**

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution. ☐ 5

**Experimental Design (5 marks)**

(Please check the appropriate level and enter mark in Space I)

None ______ 0
Faulty (requires an initial CLUE) ______ 2
Faulty (does not require an initial CLUE) ______ 3
Good and Workable ______ 5

**Clues (9 marks)**

(Please check the **CLUES** that were given to the student. Enter the net marks obtained by the student for **CLUES** in Space II)

Net Mark = 9 - (CLUES used)

CLUE No. 1 ________
CLUE No. 2 ________
CLUE No. 3 ________
CLUE No. 4 ________
CLUE No. 5 ________

Procedural CLUE ________

**Performance (11 marks)**

(Please enter the appropriate mark in Space III)

Marks are awarded on the basis of the % error in the experimental data

Experimental Error
>30% ____ 0
20-30% ____ 1
10-20% ____ 2
<10% ____ 3

Calculations
a) Step 1 ____ 2
b) Step 2 ____ 1
c) Step 3 ____ 2

Identification of the metal. ____ 3

**Experimental Design** ○ I

**Clues** ○ II

**Performance** ○ III

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**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# CLUE Model PROBLEM NO. 4

## I. INTRODUCTION

A common problem faced by chemists is to determine the concentration of an acid solution. There are various techniques for doing this.

## II. SPECIAL LAB KIT

Hydrochloric acid solution, HCl, (0.1 mol/L), 250 mL
Sodium hydroxide solution, NaOH, (0.1 mol/L), 250 mL
4 acid solutions (A, B, C, D) of unknown concentration in the range of 0.0001 mol/L to 0.20 mol/L
Stop watch (watch or clock with "sweep" second hand)
magnesium ribbon (1 m)
Bromothymol blue solution
pH paper
crayon pencil

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to arrange the 4 unknown acids A, B, C and D in decreasing order of concentration. The range in concentrations of the unknowns is from 0.0001 mol/L to 0.20 mol/l.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min.

(2) Time allowed for the Experimental Design 15 min.

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 3 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 4) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min. you will be given a clue if the design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (total possible score..............25)

| Design | | Clues | Performance | |
|---|---|---|---|---|
| NONE | 0 | No.1__4 | 4 correct | 11 |
| FAULTY (requires an initial clue) | 2 | No.2__2 | 3 correct | 7 |
| FAULTY (does not require an initial clue) | 3 | No.3__2 | 2 correct | 4 |
| GOOD AND WORKABLE | 5 | No.4__9 | 1 correct | 1 |
| | | | 0 correct | 0 |

NOTE: (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

## VIII. CLUES

### Clue No. 1

(a) pH paper changes colour with changes in acid concentration.

or

(b) The rates of chemical reactions depend on the concentrations of the reactants.

or

(c) Acids are neutralized by bases.

### Clue No. 2

The use made of Clue No. 2, 3 and 4 will vary with the progress already made by the student. The student may not need all of the three sections of Clue No. 2.

(a) Dilution of the 0.1 mol/L hydrochloric acid (HCl) will give acids of different concentrations which will produce different colours with the pH paper.

or

(b) The rate of production of hydrogen gas from magnesium will give a measure of acid concentration in the unknown.

or

(c) By measuring the amount of 0.1 mol/L sodium hydroxide solution (NaOH) necessary to neutralize the acid, the concentrations of the unknown acids can be compared.

### Clue No. 3

(a) Prepare 0.01, 0.001, and 0.0001 mol/L hydrochloric acid solutions; test the known and the unknown solutions with pH paper.

or

(b) Compare the rate of production of gas bubbles on the four strips of magnesium ribbon.

or

(c) Titrate 10 mL portions of each acid with the 0.1 mol/L sodium hydroxide solution. Use bromothymol blue indicator to determine the volume of sodium hydroxide solution required to neutralize each of the acid solutions.

Procedural Clue (Clue No. 4)

(a)
1. Prepare 10 mL of 0.01 mol/L hydrochloric acid.
   - (i) Measure 1 mL of 0.1 mol/L hydrochloric acid in a 10 mL graduated cylinder.
   - (ii) Add water to make 10 mL of solution.
2. Prepare 10 mL of 0.001 mol/L hydrochloric acid.
   - (i) Measure 1 mL of 0.01 mol/L hydrochloric acid in a 10 mL graduated cylinder.
   - (ii) Add water to make 10 mL of solution
3. Prepare 10 mL of 0.0001 mol/L hydrochloric acid.
   - (i) Measure 1 mL of 0.001 mol/L hydrochloric acid in a 10 mL graduated cylinder.
   - (ii) Add water to make 10 mL of solution.
4. Test the 0.1, 0.01, 0.001, and 0.0001 mol/L hydrochloric acid solutions with pH paper.
5. Test the solutions labelled A, B, C and D with pH paper.
6. Arrange the unknown solutions (A, B, C and D) in order of decreasing concentration as indicated by the pH paper.

or

(b)
1. Prepare four (4) strips of magnesium ribbon each approximately 4 cm in length.
2. Pour solutions A, B, C and D into separate test tubes, each to a depth of approximately 4 cm.
3. Label the test tubes A, B, C and D.
4. Put the magnesium strips into each of the test tubes.
5. Arrange the test tubes according to rate of reaction.

or

(c)
1. Pour 5 mL of solutions A, B, C and D into separate test tubes.
2. Label the test tubes A, B, C and D.
3. Add 3 drops of bromothymol blue solution to each of the four test tubes.
4. Add 0.1 mol/L sodium hydroxide, dropwise to each test tube until the bromothymol blue changes colour.
5. Count the number of drops added to each test tube.
6. Arrange the solutions in order of decreasing concentration.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

The student has a choice of at least three (3) procedures that can be followed using the materials in the lab kit.

### (a) Use of pH paper

(i) Prepare a series of diluted standards by diluting the 0.1 mol/L HCl (given) with distilled water.
(ii) Test the pH - or - compare the colours of the pH paper in each of the diluted samples.

(iii) Test the pH - or - compare the colours of the pH paper in each of the unknowns.
(iv) Arrange the unknowns in the same colour order as the diluted standards.

### (b) Rate or Reaction

(i) Prepare four strips of Mg ribbon of the same length.
(ii) Allow the lengths of Mg ribbon to react with equal volumes of each of the "unknown" acids.
(iii) Compare the rate of production of gas bubbles on the four strips of magnesium ribbon.
(iv) The more concentrated the acid the faster the bubbles are produced.

### (c) Titration

(i) Place equal volumes of each of the unknown acids in each of four test tubes.
(ii) Add a few drops of bromothymol blue indicator solution to each sample of acid. The solutions will turn yellow.
(iii) Add 0.1 mol/L sodium hydroxide (NaOH), solution dropwise to each of the acids until the solution turns green or blue; count the number of drops of NaOH solution required.
(iv) The more concentrated acid solutions will require larger volumes of sodium hydroxide solution for complete neutralization.

## X. SPECIFIC LABORATORY AND SECURITY ARRANGEMENTS

1. The individual teacher may choose to omit one or more procedures simply by omitting materials from the SPECIAL LAB KIT.

2. Students in the laboratory at the same time may have the same coding (A, B, C and D). The coding must be changed for succeeding groups of students.

3. Provide sufficient test tubes, and distilled water so that students can rinse equipment easily.

4. The acid solutions need not be prepared and standardized carefully. It is sufficient for the teacher to know the decreasing order of concentrations.

5. The teacher may choose to use acid solutions more concentrated than 0.1 mol/L.

6. The teacher must decide how to supply the clues. It may be better to give students only one of the sections of clues 2, 3 and 4. The section(s) given to the student will be determined by the progress (or lack of progress) made by the students.

**CLUE Model PROBLEM NO. 4**

**Scoring Guide**

Student ____________________

Date ____________________

Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
6. ______________________
7. ______________________
8. ______________________
9. ______________________

______________________

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**For Teacher's Use Only**

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution. ☐ 5

**Experimental Design (5 marks)**

(Please check the appropriate level and enter mark in Space I)

| | | |
|---|---|---|
| None | ______ | 0 |
| Faulty (requires an initial CLUE) | ______ | 2 |
| Faulty (does not require an initial CLUE) | ______ | 3 |
| Good and Workable | ______ | 5 |

**Clues (9 marks)**

(Please check the **CLUES** that were given to the student. Enter the net marks obtained by the student for **CLUES** in Space II)

Net Mark = 9 - (CLUES used)

| | |
|---|---|
| CLUE No. 1 | 4 |
| CLUE No. 2 | 2 |
| CLUE No. 3 | 2 |
| Procedural CLUE | 9 |

**Performance (11 marks)**

(Please enter the appropriate mark in Space III)

| | |
|---|---|
| 4 correct | 11 |
| 3 correct | 7 |
| 2 correct | 4 |
| 1 correct | 1 |
| 0 correct | 0 |

**Experimental Design** ○ I

**Clues** ○ II

**Performance** ○ III

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# CLUE Model PROBLEM NO. 5

## I. INTRODUCTION

Many chemical compounds are coloured due to the presence of specific ions or combinations of ions. In this problem you will be asked to determine which ions or combination of ions form a coloured product.

## II. SPECIAL LAB KIT

0.1 mol/L solutions of:

| | | | |
|---|---|---|---|
| 1. | KSCN | Potassium thiocyanate | |
| 2. | KCl | Potassium chloride | |
| 3. | NaSCN | Sodium thiocyanate | spot plates (white or colourles |
| 4. | $Fe(NO_3)_3$ | Iron(III) nitrate | crayon pencil |
| 5. | $FeCl_3$ | Iron(III) chloride | glass plate (10 cm X 10 cm) |
| 6. | $Cu(NO_3)_2$ | Copper(II) nitrate | eye droppers |

## III. PROBLEM

Some combinations or pairs of the above solutions produce a deep red coloured solution due to the reaction between two of the ions present to form a complex ion which is this colour.

Using only the materials in the SPECIAL LAB KIT design an experiment to identify the pair of ions which react to form the coloured species.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

Design an experiment to determine what factors might influence the depth of colour produced.

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 3 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 4) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you will be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.....25)

| DESIGN (5 marks) | | CLUES (9 marks) | | PERFORMANCE (11 marks) | |
|---|---|---|---|---|---|
| NONE | 0 | No. 1 | 3 | Correct identification | |
| | | | | of Ion No.1 | 4 |
| FAULTY (requires an initial clue) | 2 | No. 2 | 2 | of Ion No.2 | 4 |
| | | No. 3 | 3 | Correct combinations of solutions that produce a deep red colour | 3 |
| FAULTY (does not require an initial clue) | 3 | No. 4 | 9 | | |
| GOOD AND WORKABLE | 5 | | | | |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. CLUES

### Clue No. 1

Combine the solutions in pairs and determine which combinations produce a red solution.

### Clue No. 2

Determine which ions are common in the pairs of solutions which produce the red colour.

### Clue No. 3

The ions in the solutions are:

1. $K^+$ $SCN^-$
2. $K^+$ $Cl^-$
3. $Na^+$ $SCN^-$
4. $Fe^{3+}$ $Cl^-$
5. $Fe^{3+}$ $NO_3^-$
6. $Cu^{2+}$ $NO_3^-$

### Procedural Clue (Clue No. 4)

1. Combine samples of each of the following pairs of solutions. You may use drops of each on a spot plate or in clean test tubes.

| | Solution 1 | ions | | Solution 2 | ions | |
|---|---|---|---|---|---|---|
| (i) | potassium thiocyanate | $K^+$ | $SCN^-$ | potassium chloride | $K^+$ | $Cl^-$ |
| (ii) | potassium thiocyanate | $K^+$ | $SCN^-$ | sodium thiocyanate | $Na^+$ | $SCN^-$ |
| (iii) | potassium thiocyanate | $K^+$ | $SCN^-$ | iron(III) nitrate | $Fe^{3+}$ | $NO_3^-$ |
| (iv) | potassium thiocyanate | $K^+$ | $SCN^-$ | iron(III) chloride | $Fe^{3+}$ | $Cl^-$ |
| (v) | potassium thiocyanate | $K^+$ | $SCN^-$ | copper(II) nitrate | $Cu^{2+}$ | $NO_3^-$ |
| (vi) | potassium chloride | $K^+$ | $Cl^-$ | sodium thiocyanate | $Na^+$ | $SCN^-$ |
| (vii) | potassium chloride | $K^+$ | $Cl^-$ | iron(III) nitrate | $Fe^{3+}$ | $NO_3^-$ |
| (viii) | potassium chloride | $K^+$ | $Cl^-$ | iron(III) chloride | $Fe^{3+}$ | $Cl^-$ |
| (ix) | potassium chloride | $K^+$ | $Cl^-$ | copper(II) nitrate | $Cu^{2+}$ | $NO_3^-$ |
| (x) | sodium thiocyanate | $Na^+$ | $SCN^-$ | iron(III) nitrate | $Fe^{3+}$ | $NO_3^-$ |
| (xi) | sodium thiocyanate | $Na^+$ | $SCN^-$ | iron(III) chloride | $Fe^{3+}$ | $Cl^-$ |
| (xii) | sodium thiocyanate | $Na^+$ | $SCN^-$ | copper(II) nitrate | $Cu^{2+}$ | $NO_3^-$ |
| (xiii) | iron(III) nitrate | $Fe^{3+}$ | $NO_3^-$ | iron(III) chloride | $Fe^{3+}$ | $Cl^-$ |
| (xiv) | iron(III) nitrate | $Fe^{3+}$ | $NO_3^-$ | copper(II) nitrate | $Cu^{2+}$ | $NO_3^-$ |
| (xv) | iron(III) chloride | $Fe^{3+}$ | $Cl^-$ | copper(II) nitrate | $Cu^{2+}$ | $NO_3^-$ |

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2. Select the pairs of solutions that produce the red colour.
3. The pairs of solutions that you selected should have a positive and negative ion in common; the common ions are responsible for the red colour.
4. Prepare a data table to aid in the analysis of the observations.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a) Prepare a six-by-six matrix on the glass plate or the spot plate.

| | KSCN | KCl | NaSCN | $Fe(NO_3)_3$ | $FeCl_3$ | $Cu(NO_3)_2$ |
|---|---|---|---|---|---|---|
| $Cu(NO_3)_2$ | (v) | (ix) | (xii) | (xiv) | (xv) | |
| $FeCl_3$ | (iv) | (viii) | (xi) | (xiii) | | |
| $Fe(NO_3)_3$ | (iii) | (vii) | (x) | | | |
| KCl | (i) | | | | | |
| KSCN | | | | | | |

The necessary (and sufficient) tests are numbered as in Clue No. 4.

(b) The tests can be performed on a spot plate, a ruled glass plate or in test tubes.

(c) The student should use small quantities (drops) of reagents.

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) The iron(III) chloride and iron(III) nitrate solutions should have been acidified in order to prevent precipitation of hydrolysis products.

(b) If sodium thiocyanate, NaSCN, is not available then substitute potassium thiocyanate solution (with the sodium thiocyanate label).

(c) Provide sufficient test tubes, and distilled water so that students can rinse equipment easily.

**CLUE Model**
**PROBLEM NO. 5**

**Scoring Guide**

Student ____________

Date ____________

Score ____________

**A. Experimental Design**

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

**B. Observations**

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________________________ 6. ______________________________
2. ______________________________ 7. ______________________________
3. ______________________________ 8. ______________________________
4. ______________________________ 9. ______________________________
5. ______________________________ ______________________________

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### For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

**Experimental Design (5 marks)**

(Please check the appropriate level and enter mark in Space I)

None ______ 0
Faulty (requires an initial CLUE) ______ 2
Faulty (does not require an initial CLUE) ______ 3
Good and Workable ______ 5

**Clues (9 marks)**

(Please check the **CLUES** that were given to the student. Enter the net marks obtained by the student for **CLUES** in Space II)

Net Mark = 9 - (CLUES used)

CLUE No. 1 ________
CLUE No. 2 ________
CLUE No. 3 ________

Procedural CLUE ________

**Performance (11 marks)**

(Please enter the appropriate mark in Space III)

| | |
|---|---|
| Correct identitifaction | |
| of Ion No.1 | 4 |
| of Ion No.2 | 4 |
| Correct combinations of solutions that produce a deep red colour | 3 |

**Experimental Design** ○ I

**Clues** ○ II

**Performance** ○ III

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**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# CLUE Model PROBLEM NO. 6

## I. INTRODUCTION

One of the most important areas of Chemistry is "qualitative analysis", the identification of species using a variety of techniques. In this experiment you shall attempt to distinguish among four positive ions on the basis of their reactions with various other reagents.

## II. SPECIAL LAB KIT

Dropper bottles - each containing 0.2 mol/L solutions of:

| | | | | | |
|---|---|---|---|---|---|
| 1. | Lead (II) nitrate | $Pb(NO_3)_2$ | 5. | Sodium chloride | $NaCl$ |
| 2. | Barium nitrate | $Ba(NO_3)_2$ | 6. | Sodium sulphate | $Na_2SO_4$ |
| 3. | Zinc nitrate | $Zn(NO_3)_2$ | 7. | Sodium carbonate | $Na_2CO_3$ |
| 4. | Potassium nitrate | $KNO_3$ | 8. | Sodium nitrate | $NaNO_3$ |

Two "unknown" solutions each containing one of:
$Pb^{2+}$, $Ba^{2+}$, $Zn^{2+}$ or $K^{+}$ions.
Spot plates (black and white)
Crayon (wax) pencil

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to identify which one of the four positive ions is present in each of the unknown solutions.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design. Predict the observations you expect to make; explain how these observations will be used to identify the four positive ions.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 4 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 5) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you will be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.....25)

| DESIGN (5 marks) | | CLUES (9 marks) | | PERFORMANCE (11 marks) | |
|---|---|---|---|---|---|
| NONE | 0 | No. 1 | 2 | Correct scheme for analysis | 4 |
| FAULTY (requires an initial clue) | 2 | No. 2 | 2 | Correct identity of unknown No. 1 | 4 |
| | | No. 3 | 2 | | |
| FAULTY (does not require an initial clue) | 3 | No. 4 | 2 | Correct identity of unknown No. 2 | 3 |
| GOOD AND WORKABLE | 5 | No. 5 | 9 | | |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. CLUES

Clue No. 1

Some combinations of ions produce precipitates when combined in the same solution.

Clue No. 2

1. Test small quantities of 0.2 mol/L solutions of lead(II) nitrate barium nitrate, zinc nitrate and magnesium nitrate with each of the 0.2 mol/L solutions of sodium chloride, sodium sulphate and sodium carbonate.
2. Observe which combinations produce precipitates.

Clue No. 3

Test small quantities of the unknown sample solution with each reagent and compare the results with the results observed with the test (known) solutions.

Clue No. 4

Sodium nitrate is soluble in water.
The ions used for the precipitation reactions are:

chloride, $Cl^-$ sulphate, $SO_4^{2-}$ carbonate, $CO_3^{2-}$

The "unknown" ions were chosen so that:

a) one of the unknown ions produces a soluble chloride, a soluble sulphate and a soluble carbonate.

b) one of the unknown ions produces a soluble chloride and a soluble sulphate, but an insoluble carbonate.

c) one of the unknown ions produces a soluble chloride, but an insoluble sulphate and an insoluble carbonate.

d) one of the unknown ions produces an insoluble chloride, an insoluble sulphate and an insoluble carbonate.

Procedural Clue (Clue No. 5)

1. Combine samples of the lead(II) nitrate solution with each of the sodium chloride, sodium sulphate and sodium carbonate solutions. You may use a spot plate, test tubes or the glass plate for the tests.
2. Repeat with the barium nitrate solution.
3. Repeat with the zinc nitrate solution.
4. Repeat with potassium nitrate solution.
5. Repeat with unknown No. 1.
6. Repeat with unknown No. 2.
7. Compare the observations made with unknowns with the observations made with the four "known" solutions.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a) Determine, using the known solutions, the solubilities of the various "unknown" ions; repeat with the unknowns

| | | | |
|---|---|---|---|
| Insoluble | $PbCl_2$ | | |
| | $PbSO_4$ | $BaSO_4$ | |
| | $PbCO_3$ | $BaCO_3$ | $ZnCO_3$ |
| Soluble | $KCl$ | $ZnCl_2$ | $BaCl_2$ |
| | $K_2SO_4$ | $ZnSO_4$ | |
| | $K_2CO_3$ | | |

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Give each student two (2) different unknown samples - each in a stoppered, labelled test tube.

(b) Provide a variety of different unknowns around the laboratory.

(c) Number the unknowns consecutively from 1, 2, 3 ......

(d) The black spot plates are very useful so that white precipitates can be observed easily.

(e) Test the solutions before use by the students. Concentrations (within limits) are important for the appropriate precipitates to form.

(f) The sodium nitrate solution is not necessary in order to solve the problem.

# CLUE Model PROBLEM NO. 6

## Scoring Guide

Student ____________________

Date ____________________

Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
6. ______________________
7. ______________________
8. ______________________
9. ______________________

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### For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution. ☐ 5

**Experimental Design (5 marks)**

(Please check the appropriate level and enter mark in Space I)

| | | |
|---|---|---|
| None | ______ | 0 |
| Faulty (requires an initial CLUE) | ______ | 2 |
| Faulty (does not require an initial CLUE) | ______ | 3 |
| Good and Workable | ______ | 5 |

**Clues (9 marks)**

(Please check the **CLUES** that were given to the student. Enter the net marks obtained by the student for **CLUES** in Space II)

Net Mark = 9 - (CLUES used)

| | |
|---|---|
| CLUE No. 1 | ______ |
| CLUE No. 2 | ______ |
| CLUE No. 3 | ______ |
| CLUE No. 4 | ______ |
| Procedural CLUE | ______ |

**Performance (11 marks)**

(Please enter the appropriate mark in Space III)

| | |
|---|---|
| Correct scheme for analysis | 4 |
| Correct identity of unknown No. 1 | 4 |
| Correct identity of unknown No. 2 | 3 |

**Experimental Design** ○ I

**Clues** ○ II

**Performance** ○ III

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**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

**CLUE Model PROBLEM NO. 7**

## I. INTRODUCTION

Many substances decompose when heated. It is useful for the chemist to know the products of the decomposition reactions.

## II. SPECIAL LAB KIT

cobalt(II) nitrate hexahydrate (solid), $Co(NO_3)_2 \cdot 6H_2O$ (s)
concentrated nitric acid
fume hood or fume vent
litmus paper (red and blue)
cobalt chloride test paper
copper turnings

## III. PROBLEM

Cobalt nitrate hexahydrate, $Co(NO_3)_2 \cdot H_2O$ decomposes when heated. Four possible decomposition reations are listed below. In each case the states of matter are indicated.

| | solid | | solid | | gas | | gas | | gas |
|---|---|---|---|---|---|---|---|---|---|
| (i) | $3Co(NO_3)_2 \cdot 6H_2O$ | → | $Co_3N_2$ | + | $4NO_2$ | + | $5O_2$ | + | $18H_2O$ |
| (ii) | $2Co(NO_3)_2 \cdot 6H_2O$ | → | $2CoO$ | + | $4NO_2$ | + | $O_2$ | + | $12H_2O$ |
| (iii) | $3Co(NO_3)_2 \cdot 6H_2O$ | → | $Co_3N_2$ | + | $4NO$ | + | $7O_2$ | + | $18H_2O$ |
| (iv) | $Co(NO_3)_2 \cdot 6H_2O$ | → | $CoO$ | + | $N_2$ | + | $5H_2O_2$ | + | $H_2O$ |

Using only the materials in the SPECIAL LAB KIT design an experiment to identify the equation which correctly illustrates the thermal decomposition of cobalt(II) nitrate hexahydrate. As a preliminary step heat a sample (5 mm depth) in a test tube and observe carefully.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

### V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

### VI. TEST FORMAT

CAUTION: All experimental work for this problem must be performed in a well-vented area. The teacher must approve the work area.

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 4 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 5) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you will be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

### VII. EVALUATION SCHEME (Total possible score.....25)

| DESIGN (5 marks) | | CLUES (9 marks) | | PERFORMANCE (11 marks) | |
|---|---|---|---|---|---|
| NONE | 0 | No. 1 | ___2 | Correct equation | 11 |
| FAULTY (requires an initial clue) | 2 | No. 2 | ___2 | Three products correct | 6 |
| | | No. 3 | ___2 | Two products correct | 1 |
| FAULTY (does not require an initial clue) | 3 | No. 4 | ___2 | Less than two products correct | 0 |
| GOOD AND WORKABLE | 5 | No. 5 | ___9 | | |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. CLUES

Clue No. 1

Heat a small sample of the cobalt nitrate hexahydrate until no further changes are evident. Attempt to identify the water and any other substances that are produced. Cobalt chloride paper is used to verify the presence of water.

Clue No. 2

What is the orange-brown coloured gas?
Add a small quantity of nitric acid to some copper turnings.
CAUTION - work in a well ventilated area; nitric acid is corrosive!

Clue No. 3

Weigh out a larger sample of the substance and heat until no further changes take place - then weigh the residue.

Clue No. 4

The amount of cobalt in the residue is the same as in the sample.

% Co in $Co(NO_3)_2 \cdot 6H_2O$ = 22%

% Co in $Co_3N_2$ = 86%

% Co in CoO = 79%

The mass of 1 mol of $Co(NO_3)_2 \cdot 6H_2O$ is 291 g.

The mass of 1 mol of $Co_3N_2$ is 205 g.

The mass of 1 mol of CoO is 75 g.

Procedural Clue (Clue No. 5)

1. Heat a small sample of the cobalt nitrate hexahydrate in a test tube.
2. Test the products evolved with cobalt chloride paper and with a glowing splint. Cobalt chloride paper turns pink in water.
3. Compare the colour of the gas produced by the reaction of copper with nitric acid and the gas produced by the heating of the cobalt nitrate hexahydrate.

Caution: The gas is poisonous - work in a well-vented area only.

4. Weigh an empty crucible. Place about 10 g of cobalt nitrate hexahydrate in the crucible and weigh again.
5. Heat the crucible until no further changes in the materials are evident.
6. Allow the crucible to cool to room temperature and re-weigh.
7. Determine the weight of the residue.
8. 1 mol of CoO is produced from 1 mol of $Co(NO_3)_2 \cdot 6H_2O$
   1 mol of $Co_3N_2$ is produced from 3 mol of $Co(NO_3)_2 \cdot 6H_2O$
9. Calculate the number of moles of residue.

$$\text{No. of moles of } Co(NO_3)_2 \cdot 6H_2O = \frac{\text{g of } Co(NO_3)_2 \cdot 6H_2O}{291}$$

$$\text{No. of moles of } Co_3N_2 = \frac{\text{g of residue}}{205}$$

$$\text{No. of moles of CoO} = \frac{\text{g of residue}}{75}$$

10. Compare the number of moles of residue with the initial number of moles of cobalt nitrate hexahydrate that you heated.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a) Heat a small sample of $Co(NO_3)_2 \cdot 6H_2O$ in a test tube to obtain some qualitative observations.

(b) The presence of water can be verified by the cobalt chloride test. (Equation No. 3 is eliminated).

(c) The brownish-red gas is the same as that produced in the reaction between copper and nitric acid ($NO_2$). (Equation No. 4 is eliminated)

The identity of the brownish-red gas is not necessary in order to eliminate equation No. 4. The students should know that neither nitrogen ($N_2$) nor oxygen ($O_2$) is coloured.

(d) A positive "glowing splint" test should be verification of the presence of oxygen.

(e) Heat a larger sample (10 g) of the cobalt nitrate hexahydrate in a crucible. Continue heating until there is no further change.

The weight of the residue can be used to show that the residue is CoO rather than $Co_3N_2$.

$$\frac{\text{g of residue}}{75} = \text{No. of moles of CoO}$$

$$\frac{\text{g of residue}}{205} = \text{No. of moles of } Co_3N$$

If: No. of mol of CoO = No. of mol of $Co(NO_3)_2 \cdot 6H_2O$
Then the residue is CoO.

If: No. of mol of CoO = 1/3 No. of moles of $Co(NO_3)_2 \cdot 6H_2O$
Then the residue is $Co_3N$.

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Students MUST be supervised carefully; $NO_2$ is poisonous. Allow the students to work only in a fume hood or in an exceptionally well-vented area.

(b) This may be a more challenging problem than some others; give this problem to the more able students who may respond positively to the greater challenge.

(c) Provide the sample of cobalt(II) nitrate hexahydrate in a labelled test tube. Provide at least 15 g of the sample.

(d) Only very careful work will allow the students to distinguish between the number of moles of CoO and the number of moles of $Co_3N_2$ when compared with the number of moles of cobalt(II) nitrate hexahydrate used in the experiment.

**CLUE Model**
**PROBLEM NO. 7**

**Scoring Guide**

Student ____________________

Date ____________________

Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
6. ______________________
7. ______________________
8. ______________________
9. ______________________

______________________

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### For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution. ☐ 5

**Experimental Design (5 marks)**

(Please check the appropriate level and enter mark in Space I)

| | | |
|---|---|---|
| None | ______ | 0 |
| Faulty (requires an initial CLUE) | ______ | 2 |
| Faulty (does not require an initial CLUE) | ______ | 3 |
| Good and Workable | ______ | 5 |

**Clues (9 marks)**

(Please check the **CLUES** that were given to the student. Enter the net marks obtained by the student for **CLUES** in Space II)

Net Mark = 9 - (CLUES used)

| | |
|---|---|
| CLUE No. 1 | ______ |
| CLUE No. 2 | ______ |
| CLUE No. 3 | ______ |
| CLUE No. 4 | ______ |
| Procedural CLUE | ______ |

**Performance (11 marks)**

(Please enter the appropriate mark in Space III)

| | |
|---|---|
| Correct equation | 11 |
| Three products correct | 6 |
| Two products correct | 1 |
| Less than two products correct | 0 |

**Experimental Design** ○ I

**Clues** ○ II

**Performance** ○ III

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

**CLUE Model PROBLEM NO. 8**

## I. INTRODUCTION

Chemists often find it necessary to find the concentration of an acidic or basic solution.

## II. SPECIAL LAB KIT

Solution of unknown concentration
NaOH, sodium hydroxide solution, 0.200 mol/L
HCl, hydrochloric acid solution, 0.200 mol/L
litmus paper
bromothymol blue solution
phenolphthalein solution
magnesium ribbon

(the actual concentrations are noted on the bottles)

## III. PROBLEM

The unknown solution provided to you is either an acidic or basic solution of unknown concentration. Before proceeding with your Design determine, experimentally, whether your solution is acidic or basic.

Using only the materials in the SPECIAL LAB KIT design an experiment to determine the concentration of the solution.

Express the concentration in terms of moles of hydrogen ion, $H^+(aq)$ or moles of hydroxyl ion, $OH^-(aq)$ per litre of solution.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 5 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 6) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you will be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.....25)

| DESIGN (5 marks) | |
|---|---|
| NONE | 0 |
| FAULTY (requires an initial clue) | 2 |
| FAULTY (does not require an initial clue) | 3 |
| GOOD AND WORKABLE | 5 |

| CLUES (9 marks) | |
|---|---|
| No. 1 | 2 |
| No. 2 | 2 |
| No. 3 | 1 |
| No. 4 | 1 |
| No. 5 | 2 |
| No. 6 | 9 |

| PERFORMANCE (11 marks) | |
|---|---|
| 1. Class of solution | 2 |
| 2. Calculations | 2 |
| 3. Concentration Marks are awarded on the basis of the % error in the experimental data. | |
| >25% | 0 |
| 15 - 25% | 1 |
| 5 - 15% | 3 |
| 1 - 5% | 5 |
| < 1% | 7 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. CLUES

Clue No. 1
The indicators can be used to determine if the unknown is an acidic or basic solution.

Clue No. 2
The concentration of the unknown can be determined by titration.

Clue No. 3
Repeat the titration in order to obtain more precise data.

Clue No. 4
The number of moles of hydrogen ion is equal to the number of moles of hydroxide ion at neutrality.

Clue No. 5
No. of moles of hydrogen ion
= Volume (L) x Concentration of HCl (mol/L)

and No. of moles of hydroxide ion
= Volume (L) x Concentration NaOH (mol/L)

Procedural Clue (Clue No. 6)

1. Determine the acidic and basic colours of a given indicator, bromothymol blue, by adding two drops of bromothymol blue solution to individual test tubes containing samples of the sodium hydroxide and hydrochloric acid solutions.

2. Use the same indicator, bromothymol blue, to determine if the unknown is an acid or a base.

3. Use a pipet or a graduated cylinder to transfer 25 mL of the unknown solution to an Erlenmeyer flask.

4. Add 3 drops of bromothymol blue solution to the unknown.

5. a) If the unknown solution is blue -
   (i) With a graduated pipet or a buret add hydrochloric acid (0.2 mol/L) until the until the solution turns green.
   (ii) Measure the volume of hydrochloric acid solution required to carry out the neutralization.
   b) If the unknown solution is yellow -
   (i) With a graduated pipet or a buret, add sodium hydroxide (0.2 mol/L) until the solution turns green.
   (ii) Measure the volume of sodium hydroxide solution required to carry out the neutralization.
6. Repeat step 5 in order to obtain more precise data.
7. Calculations
   (i) Calculate the number of moles of acid/base used to neutralize the 25 mL of unknown sample.
   (ii) No. of moles of acid ($H^+$) = Volume (L) x Concentration (mol/L).
   (iii) No. of moles of acid ($H^+$) = No. of moles of base ($OH^-$).
   (iv) Calculate the number of moles of $H^+$ or $OH^-$ in the 25 mL sample of the unknown.
   (v) Calculate the number of moles of $H^+$ or $OH^-$ in 1 L of the unknown solution.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Provide known solutions of sodium hydroxide and hydrochloric acid with the concentrations shown on the labels. Quote concentrations to three significant digits (0.211 mol/L, for example).

(b) Do NOT provide the same known solutions to all students. Vary the concentrations of the known samples.

(c) Prepare a variety of acidic and basic unknowns (numbered) for student use.

## CLUE Model PROBLEM NO. 8

**Scoring Guide**

Student ____________________

Date ____________________

Score ____________________

### A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

### B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______
2. ______
3. ______
4. ______
5. ______
6. ______
7. ______
8. ______
9. ______

______

---

### For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

**Experimental Design (5 marks)**

(Please check the appropriate level and enter mark in Space I)

| | |
|---|---|
| None | ______ 0 |
| Faulty (requires an initial CLUE) | ______ 2 |
| Faulty (does not require an initial CLUE) | ______ 3 |
| Good and Workable | ______ 5 |

**Clues (9 marks)**

(Please check the **CLUES** that were given to the student. Enter the net marks obtained by the student for **CLUES** in Space II)

Net Mark = 9 - (CLUES used)

| | |
|---|---|
| CLUE No. 1 | ______ |
| CLUE No. 2 | ______ |
| CLUE No. 3 | ______ |
| CLUE No. 4 | ______ |
| CLUE No. 5 | ______ |
| Procedural CLUE | ______ |

**Performance (11 marks)**

(Please enter the appropriate mark in Space III)

| | |
|---|---|
| Class of solution | 2 |
| Calculations | 2 |

Concentration Marks are awarded on the basis of the % error in the experimental data.

| | |
|---|---|
| >25% | ______ 0 |
| 15 - 25% | ______ 1 |
| 5 - 15% | ______ 3 |
| 1 - 5% | ______ 5 |
| <1% | ______ 7 |

**Experimental Design** ○ I

**Clues** ○ II

**Performance** ○ III

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# CLUE Model PROBLEM NO. 9

## I. INTRODUCTION

The passage of an electrical current through an aqueous solution may result in the decomposition of the dissolved species or of the solvent. Chemists are frequently faced with the problem of identifying the products of electrolysis.

## II. SPECIAL LAB KIT

- DC power supply
- leads with alligator clips
- U-tube
- trichlorotrifluoroethane
- eye droppers
- nitric acid
- unknown solution
- rubber tubing
- carbon rods
- zinc strips
- copper strips
- aluminum strips
- rubber stoppers
- litmus paper
- wood splints
- limewater

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to identify the materials that are produced when the unknown solution is electrolyzed.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 6 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 7) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you will be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.....25)

| DESIGN (5 marks) | | CLUES (9 marks) | | PERFORMANCE (11 marks) | |
|---|---|---|---|---|---|
| NONE | 0 | No. 1 | 1 | 1. Identity of product (No. 1) | 4 |
| FAULTY (requires an initial clue) | 2 | No. 2 | 2 | 2. Identity of product (No. 2) | 4 |
| FAULTY (does not require an initial clue) | 3 | No. 3 | 2 | 3. Electrode identification | 3 |
| GOOD AND WORKABLE | 5 | No. 4 | 1 | | |
| | | No. 5 | 1 | | |
| | | No. 6 | 1 | | |
| | | No. 7 | 9 | | |

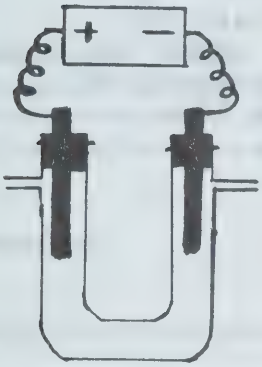
NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

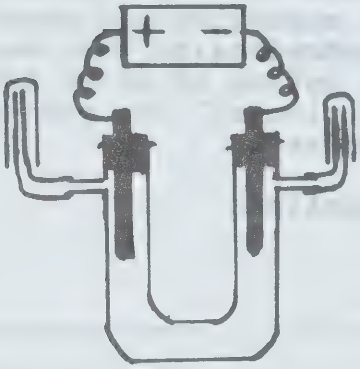
SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. CLUES

Clue No. 1



Clue No. 3



Clue No. 2
Many gases can be collected by the displacement of air.

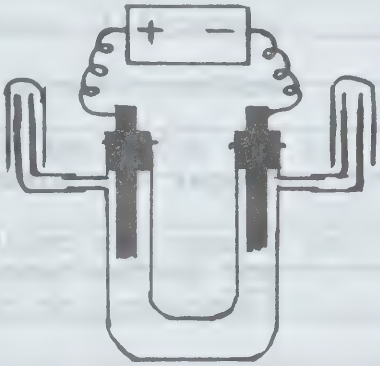
Clue No. 4
Gases can often be identified by their action on burning or glowing splints.

Clue No. 5
The halogens each produce characteristic colours when dissolved in trichlorotrifluoroethane.

Clue No. 6
The choice of electrodes limits the number of metals that may be plated out of an aqueous solution.

Procedural Clue (Clue No. 7)

1. Connect the output terminals of the power supply to the carbon electrodes.
2. Place short lengths of rubber tubing on the side arms of the U-tube.
3. Invert small test tubes over the lengths of rubber tubing.
4. Activate the power supply and observe.
5. Test the gas(es) collected with a
   (a) burning splint
   (b) glowing splint
   (c) few drops of trichlorotrifluoroethane



6. Observe any solid that accumulates on the electrode(s).
7. Immerse the tips of the electrodes in a few mL of concentrated nitric acid in a small test tube.
8. The colour of the solution and the gases formed may be an indication of the presence and identity of a solid product.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Sample "unknown" solutions that may be used:

copper(II) chloride

copper(II) bromide

copper(II) iodide

sodium chloride

hydrochloric acid

magnesium bromide

potassium iodide

sodium bromide

(b) The solutions may all be coloured blue - to simulate a copper ion solution.

(c) Change the coding scheme for those candidates who are NOT in the laboratory at the same time. Students in the laboratory at the same time can have the same coding.

**CLUE Model PROBLEM NO. 9**

**Scoring Guide**

Student ____________________

Date ____________________

Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________
7. ____________________
8. ____________________
9. ____________________

____________________

---

**For Teacher's Use Only**

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

**Experimental Design (5 marks)**

(Please check the appropriate level and enter mark in Space I)

| | | |
|---|---|---|
| None | ______ | 0 |
| Faulty (requires an initial CLUE) | ______ | 2 |
| Faulty (does not require an initial CLUE) | ______ | 3 |
| Good and Workable | ______ | 5 |

**Clues (9 marks)**

(Please check the CLUES that were given to the student. Enter the net marks obtained by the student for CLUES in Space II)

Net Mark = 9 - (CLUES used)

| | |
|---|---|
| CLUE No. 1 | ______ |
| CLUE No. 2 | ______ |
| CLUE No. 3 | ______ |
| CLUE No. 4 | ______ |
| CLUE No. 5 | ______ |
| CLUE No. 6 | ______ |
| Procedural CLUE | ______ |

**Performance (11 marks)**

(Please enter the appropriate mark in Space III)

| | |
|---|---|
| Identity of product (No. 1) | 4 |
| Identity of product (No. 2) | 4 |
| Electrode identification | 3 |

**Experimental Design** ○ I

**Clues** ○ II

**Performance** ○ III

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# CLUE Model PROBLEM NO. 10

## I. INTRODUCTION

A characteristic property of a substance is its solubility in water. Sometimes the chemist must devise different methods to determine the solubilities of different substances.

## II. SPECIAL LAB KIT

10 mL graduated cylinders
medicine droppers
conductivity apparatus
porcelain dish
calcium hydroxide (solid)
calcium chloride solution (0.100 mol/L)
sodium carbonate solution (0.100 mol/L)
ammonium chloride solution (0.100 mol/L)
ammonium carbonate solution (0.100 mol/L)
thermometer ($-10^{\circ}$ - $110^{\circ}$C)
saturated calcium hydroxide solution (limewater)
$H_2SO_4$ (0.025 mol/L)
litmus paper
phenolphthalein solution
bromothymol blue solution
HCl (0.050 mol/L)
pipets
centigram balance
filter paper
buret
soda straws

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to determine the solubility (grams of calcium hydroxide per litre of solution) of calcium hydroxide in water.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design. Predict the observations you expect to make. Explain how you will use these observations to determine the solubilty of calcium hydroxide.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

| | |
|---|---|
| (1) Time allowed for the complete problem | 40 min |
| (2) Time allowed for the Experimental Design | 15 min |

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 4 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 5) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you will be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.....25)

DESIGN (5 marks)

| | |
|---|---|
| NONE | 0 |
| FAULTY (requires an initial clue) | 2 |
| FAULTY (does not require an initial clue) | 3 |
| GOOD AND WORKABLE | 5 |

CLUES (9 marks)

No. 1 ___(1)

No. 2 ___(2)

No. 3 ___(2)

No. 4 ___(3)

No. 5 ___(9)

PERFORMANCE (11 marks)

1. Marks are awarded on the basis of the % error in the experimental data.

| Experimental Error | |
|---|---|
| >50% | 0 |
| 30-50% | 1 |
| 20-30% | 3 |
| 10-20% | 4 |
| <10% | 7 |

2. Calculations -

| | |
|---|---|
| a) Step 1 | 2 |
| b) Step 2 | 1 |
| c) Step 3 | 1 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. CLUES

### Clue No. 1

The solubility of a solution refers to the concentration of a saturated solution.

### Clue No. 2

The solubility of a solute in a given solvent can be determined either by synthesis (preparation of the solution) or by analysis of the solution.

Calcium hydroxide solution can be analyzed by:

a) titration
b) precipitation
c) evaporation

### Clue No. 3

a) Titration - determine the quantity of acid required to neutralize a given volume of saturated calcium hydroxide solution.

b) Precipitation - Quantitatively precipitate, filter, dry and determine the mass of an insoluble carbonate, or other substance.

c) Evaporation - determine the mass of residue remaining after a sample of the solution is evaporated to dryness.

### Clue No. 4

Calculate the mass of calcium hydroxide per litre of solution.

a) Titration

$Ca(OH)_2$ Mass of 1 mol = [40 + 2(16 +1)]g = 74 g

No. of moles of $OH^-(aq)$ = No. of moles of $H^+(aq)$

No. of moles of $Ca(OH)_2$ = 1/2 (No. of moles of HCl)

No. of moles of $Ca(OH)_2$ = No. of moles of $H_2SO_4$

b) Precipitation

No. of moles of $Ca(OH)_2$ = No. of moles of $CaCO_3$

Mass of 1 mol of $CaCO_3$ = [40 + 12 + (3 x 16)]g = 100 g

c) Evaporation

Mass of 1 mol of CaO = (40 +16)g = 56 g

Mass of 1 mol of $Ca(OH)_2$ = [40 + 2 (16 + 1)]g = 74 g

No. of moles of CaO = No. of moles of $Ca(OH)_2$

Procedural Clue (Clue No. 5)

1. Use a pipet to transfer 25 mL of calcium hydroxide solution to an Erlenmeyer flask.

2. Add three drops of bromothymol blue solution to the calcium hydroxide solution.

3. Use a buret to add sulfuric acid solution (0.100 mol/L) to the calcium hydroxide solution until the indicator turns green.

4. Measure and record the volume of sulphuric acid solution consumed.

5. Repeat the procedure using a second 25 mL sample of calcium hydroxide solution.

6. Calculate the number of moles of sulphuric acid consumed.

7. Calculate the number of moles of calcium hydroxide in the original sample.

8. Determine the solubility of calcium hydroxide in g/L.

9. Calculations:

   a) No. of moles of sulfuric acid
      = Volume (L) x Concentration (mol/L)

   b) No. of moles of calcium hydroxide
      = No. of moles of sulfuric acid

   c) Mass of calcium hydroxide
      $= V_{(L)} \times$ Mass of 1 mol of $Ca(OH)_2$

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) The unknown samples must be freshly prepared to avoid precipitation of the carbonate through reaction with carbon dioxide.

(b) The concentration of the various test solutions must be quoted to at least two significant digits.

(c) Students may be given solutions of barium hydroxide or strontium hydroxide in place of the calcium hydroxide. In this case the student must be told the identity of the "unknown" sample.
Appropriate changes would have to be made in Clue No. 4 as well as in the SPECIAL LAB KIT.

(d) Students must be familiar with the use of pipets and burets.

(e) The avenue is available for students to perform the titrations with medicine droppers.

(f) The teacher must recognize, in evaluating the student data, that the solubility of a solute in a given solvent may be a function of temperature.

(g) The units g/L were selected for this problem. The units g of solute per 100 g of solvent are recognized in problem 11.

(h) Published solubility data (Handbok of Chemistry and Physics).

| Temperature | Solubility (g/L) | | |
|---|---|---|---|
| | $Ca(OH)_2$ | $Ba(OH)_2$ | $Sr(OH)_2$ |
| 0°C | 1.85 g | 56 g | 4.1 g |
| 100°C | 0.77 g | 947 g | 218.3 g |

A preliminary titration by the teacher can be used to approximate the solubility at room temperature.

**CLUE Model**
**PROBLEM NO. 10**

### Scoring Guide

Student ________________

Date ________________

Score ________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________
7. ____________________
8. ____________________
9. ____________________

____________________

---

### For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

**Experimental Design (5 marks)**

(Please check the appropriate level and enter mark in Space I)

| | | |
|---|---|---|
| None | ______ | 0 |
| Faulty (requires an initial CLUE) | ______ | 2 |
| Faulty (does not require an initial CLUE) | ______ | 3 |
| Good and Workable | ______ | 5 |

**Clues (9 marks)**

(Please check the CLUES that were given to the student. Enter the net marks obtained by the student for CLUES in Space II)

Net Mark = 9 - (CLUES used)

| | |
|---|---|
| CLUE No. 1 | ______ |
| CLUE No. 2 | ______ |
| CLUE No. 3 | ______ |
| CLUE No. 4 | ______ |
| Procedural CLUE | ______ |

**Performance (11 marks)**

(Please enter the appropriate mark in Space III)

Marks are awarded on the basus if the % error in the experimental data.

| Experimental Error | |
|---|---|
| >50% | 0 |
| 30-50% | 1 |
| 20-30% | 3 |
| 10-20% | 4 |
| <10% | 7 |

| Calculations - | |
|---|---|
| a) Step 1 | 2 |
| b) Step 2 | 1 |
| c) Step 3 | 1 |

**Experimental Design** ○ I

**Clues** ○ II

**Performance** ○ III

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# CLUE Model PROBLEM NO. 11

## I. INTRODUCTION

A characteristic property of a substance is its solubility in water. Sometimes the chemist must devise different methods to determine the solubilities of different substances.

## II. SPECIAL LAB KIT

10 mL graduated cylinders
medicine droppers
conductivity apparatus
porcelain dish
calcium hydroxide (solid)
calcium chloride solution (0.100 mol/L)
sodium carbonate solution (0.100 mol/L)
ammonium chloride solution (0.100 mol/L)
ammonium carbonate solution (0.100 mol/L)
thermometer (-10° - 110°C)
saturated calcium hydroxide solution (limewater)
$H_2SO_4$ (0.025 mol/L)
litmus paper
phenolphthalein solution
bromothymol blue solution
HCl (0.050 mol/L)
pipets
centigram balance
filter paper
buret
soda straws

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to determine the solubility (g of solute per 100 g of solvent) of calcium hydroxide in water.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design. Predict the observations you expect to make. Explain how you will use these observations to determine the solubilty of calcium hydroxide.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 5 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 6) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you will be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.....25)

### DESIGN (5 marks)

| | |
|---|---|
| NONE | 0 |
| FAULTY (requires an initial clue) | 2 |
| FAULTY (does not require an initial clue) | 3 |
| GOOD AND WORKABLE | 5 |

### CLUES (9 marks)

No. 1 ___(1)
No. 2 ___(2)
No. 3 ___(2)
No. 4 ___(2)
No. 5 ___(1)
No. 6 ___(9)

### PERFORMANCE (11 marks)

1. Marks are awarded on the basis of the % error in the experimental data.

| Experimental Error | |
|---|---|
| >50% | 0 |
| 30-50% | 1 |
| 20-30% | 2 |
| 10-20% | 3 |
| <10% | 6 |

2. Calculations

| | |
|---|---|
| a) Step 1 | 2 |
| b) Step 2 | 1 |
| c) Step 3 | 1 |
| d) Step 4 | 1 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. CLUES

### Clue No. 1

The solubility of a solution refers to the concentration of a saturated solution.

### Clue No. 2

1. The solubility of a solute in a given solvent can be determined either by synthesis (preparation of the solution) or by analysis of the solution.

2. Calcium hydroxide solution can be analyzed by:

   a) titration
   b) precipitation
   c) evaporation

### Clue No. 3

a) Titration - determine the quantity of acid required to neutralize a given volume of saturated calcium hydroxide solution.

b) Precipitation - Quantitatively precipitate, filter, dry and determine the mass of an insoluble carbonate, or other substance.

c) Evaporation - determine the mass of residue remaining after a sample of solution is dried.

### Clue No. 4

Calculate the mass of calcium hydroxide per litre of solution.

a) Titration

$Ca(OH)_2$ Mass of 1 mol $= [40 + 2(16 + 1)]$g $= 74$ g
No. of moles of $OH^-(aq)$ = No. of moles of $H^+(aq)$
No. of moles of $Ca(OH)_2$ = 1/2 (No. of moles of HCl)
No. of moles of $Ca(OH)_2$ = No. of moles of $H_2SO_4$

b) Precipitation

No. of moles of $Ca(OH)_2$ = No. of moles of $CaCO_3$
Mass of 1 mol of $CaCO_3$ = $[40 + 12 + (3 \times 16)]$g $= 100$ g

c) Evaporation

Mass of 1 mol of CaO = $(40 + 16)$g $= 56$ g
No. of moles of CaO = No. of moles of $Ca(OH)_2$

### Clue No. 5

The mass of the sample of calcium hydroxide solution included both the mass of calcium hydroxide and the mass of water.

Procedural Clue (Clue No. 6)

1. Find the mass of an Erlenmeyer flask.
2. Use a pipet to transfer 25 mL of calcium hydroxide solution to the Erlenmeyer flask.
3. Find the mass of the flask and the sample solution.
4. Add three drops of bromothymol blue solution to the calcium hydroxide solution.
5. Use a buret to add sulfuric acid solution (0.100 mol/L) to the calcium hydroxide solution until the indicator turns green.
6. Measure and record the volume of sulphuric acid solution consumed.
7. Repeat the procedure using a second 25 mL sample of calcium hydroxide solution.
8. Calculate the number of moles of sulfuric acid consumed.
9. Calculate the number of moles of calcium hydroxide in the original sample.
10. Calculate the mass of calcium hydroxide dissolved in the 25 mL sample of solution.
11. Calculations:

    (i) No. of moles of sulfuric acid
    = Volume (L) x Concentration (mol/L)
    (ii) No. of moles of calcium hydroxide =
    = No. of moles of sulfuric acid
    (iii) Mass of calcium hydroxide
    = $V_{(L)}$ x Mass of 1 mol of $Ca(OH)_2$
    (iv) Mass of water
    = Mass of sample - Mass of calcium hydroxide

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)
(b)
(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) The unknown samples must be freshly prepared to avoid precipitation of the carbonate through reaction with carbon dioxide.
(b) The concentration of the various test solutions must be quoted to at least two significant digits.
(c) Students may be given solutions of barium hydroxide or strontium hydroxide in place of the calcicm hydroxide. In this case the student must be told the identity of the "unknown" sample.
Appropriate changes would have to be made to Clue No. 5 as well as in the SPECIAL LAB KIT.
(d) Students must be familiar with the use of pipets and burets.
(e) The avenue is available for students to perform the titrations with medicine droppers.
(f) The teacher must recognize, in evaluating the student data, that the solubility of a solute in a given solvent may be a function of temperature.
(g) The units g/100 g of a solvent were selected for this problem. The units g/L are recognized in problem 10.
(h) Published solubility data (Handbook of Chemistry and Physics).

| Temperature | Solubility (g/L)<br>(g/100 g of water) | | |
|---|---|---|---|
| | $Ca(OH)_2$ | $Ba(OH)_2$ | $Sr(OH)_2$ |
| 0°C | 0.185 g | 5.6 g | 4.1 g |
| 100°C | 0.077 g | 94.7 g | 21.83 g |

A preliminary titration by the teacher can be used to approximate the solubility at room temperature.

**CLUE Model PROBLEM NO. 11**

**Scoring Guide**

Student ____________________

Date ____________________

Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1 ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________
7. ____________________
8. ____________________
9. ____________________
____________________

---

## For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

**Experimental Design (5 marks)**

(Please check the appropriate level and enter mark in Space I)

| | |
|---|---|
| None | ____ 0 |
| Faulty (requires an initial CLUE) | ____ 2 |
| Faulty (does not require an initial CLUE) | ____ 3 |
| Good and Workable | ____ 5 |

**Clues (9 marks)**

(Please check the **CLUES** that were given to the student. Enter the net marks obtained by the student for **CLUES** in Space II)

Net Mark = 9 - (CLUES used)

| | |
|---|---|
| CLUE No. 1 | 1 |
| CLUE No. 2 | 2 |
| CLUE No. 3 | 2 |
| CLUE No. 4 | 2 |
| CLUE No. 5 | 1 |
| Procedural CLUE | 9 |

**Performance (11 marks)**

(Please enter the appropriate mark in Space III)

Marks are awarded on the basis of the % error in the experimental data.

Experimental Frror

| | |
|---|---|
| >50% | 0 |
| 30-50% | 1 |
| 20-30% | 2 |
| 10-20% | 3 |
| <10% | 6 |

Calculations

| | |
|---|---|
| a) Step 1 | 2 |
| b) Step 2 | 1 |
| c) Step 3 | 1 |
| d) Step 4 | 1 |

**Experimental Design** ○ I

**Clues** ○ II

**Performance** ○ III

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# CLUE Model PROBLEM NO. 12

## I. INTRODUCTION

The chemist is frequently called upon to separate and identify the components of a mixture. The materials are frequently similar in colour and texture, but different in use and properties.

Calcium carbonate (limestone), $CaCO_3$, is used in crushed form in road building. In the laboratory it can be used as a substitute for marble chips to produce carbon dioxide.

Calcium chloride, $CaCl_2$, is used to dry the air in humid basements; $CaCl_2$ absorbs water vapour from the air. Calcium hydroxide (slaked lime), $Ca(OH)_2$, mixed with water is used as whitewash. It can also be added to soil to counteract acidity.

## II. SPECIAL LAB KIT

calcium carbonate(s), $CaCO_3$
calcium hydroxide(s), $Ca(OH)_2$
calcium chloride(s), $CaCl_2$
bromothymol blue solution
hydrochloric acid, HCl, (0.200 mol/L)
silver nitrate solution (0.002 mol/L)
vial containing a mixture of calcium hydroxide and at least one of calcium carbonate and calcium chloride

litmus paper
buret
pipet
filter paper
funnel

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to determine the % (by mass) of calcium hydroxide in the mixture.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 6 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 7) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you will be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.....25)

| DESIGN (5 marks) | |
|---|---|
| NONE | 0 |
| FAULTY (requires an initial clue) | 2 |
| FAULTY (does not require an initial clue) | 3 |
| GOOD AND WORKABLE | 5 |

| CLUES (9 marks) | | |
|---|---|---|
| No. 1 | ___ | (1) |
| No. 2 | ___ | (1) |
| No. 3 | ___ | (2) |
| No. 4 | ___ | (2) |
| No. 5 | ___ | (1) |
| No. 6 | ___ | (1) |
| No. 7 | ___ | (9) |

PERFORMANCE (11 marks)

1. Marks are awarded on the basis of the % error in the experimental data.

| Experimental Error | |
|---|---|
| >50% | 0 |
| 30-50% | 2 |
| 20-30% | 4 |
| 10-20% | 5 |
| 10% | 8 |

2. Calculations 3

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. CLUES

Clue No. 1
The mass of the solid sample must be known for later calculations.

Clue No. 2
The components of the mixture must be separated before the analysis can be carried out.

Clue No. 3
One of the substances is insoluble in water.

Clue No. 4
Calcium hydroxide is a base. Titrate with hydrochloric acid.

Clue No. 5
No. of moles of calcium hydroxide
= 2 x (no. of moles of hydrochloric acid).

Clue No. 6

$$\%\ \text{calcium hydroxide} = \frac{\text{mass of calcium hydroxide}}{\text{mass of sample}} \times 100\%$$

Procedural Clue (Clue No. 7)

1. Determine the mass of the vial, contents and cap.
2. Empty approximately half of the contents of the vial into a 250 mL beaker containing 100 mL of water. Stir to dissolve as much of the sample as possible.
3. Determine the mass of the vial, cap and the remaining contents of the vial.
4. Filter the mixture.
5. Add 3 drops of bromothymol blue solution to the filtrate.
6. Fill a buret with hydrochloric acid (0.200 mol/L) solution.
7. Add the hydrochloric acid solution until the colour of the solution changes from blue to green.
8. Repeat the procedure to obtain confirmatory data.
9. Calculations:
   (i) No. of moles of hydrochloric acid

   $$= V(L) \times \text{Concentration (mol/L)}$$

   (ii) No. of moles of calcium hydroxide

   $$= \frac{1}{2} \times \text{No. of moles of hydrochloric acid}$$

   (iii) % calcium hydroxide

   $$= \frac{\text{Mass of calcium hydroxide}}{\text{Mass of solid mixture}} \times 100\%$$

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Samples of the solid mixtures should be prepared by careful mixing with a mortar and pestle, of samples of known mass of the three solids.

(b) The % of $Ca(OH)_2$ should be different in the samples given to students who are in the laboratory at different times.

(c) The total sample size is not significant; the sample should not contain any more than 0.2 g of calcium hydroxide.

(d) The concentration of the hydrochloric acid should be given to three significant digits (0.137 mol/L, for example).

(e) The problem can be changed to any of the other alkaline earth hydroxides. Remember to take account of the water solubility of the hydroxides before deciding on the sample size.

**CLUE Model**
**PROBLEM NO. 12**

**Scoring Guide**

Student ____________________

Date ____________________

Score ____________________

. **Experimental Design**

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

B. **Observations**

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5 ______________________
6 ______________________
7. ______________________
8. ______________________
9. ______________________
______________________

---

## For Teacher's Use Only

### Alternate Solution(s)

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

### Experimental Design (5 marks)

(Please check the appropriate level and enter mark in Space I)

| | | |
|---|---|---|
| None | ______ | 0 |
| Faulty (requires an initial CLUE) | ______ | 2 |
| Faulty (does not require an initial CLUE) | ______ | 3 |
| Good and Workable | ______ | 5 |

### Clues (9 marks)

(Please check the **CLUES** that were given to the student. Enter the net marks obtained by the student for **CLUES** in Space II)

Net Mark = 9 - (CLUES used)

| | |
|---|---|
| CLUE No. 1 | 1 |
| CLUE No. 2 | 1 |
| CLUE No. 3 | 2 |
| CLUE No. 4 | 2 |
| CLUE No. 5 | 1 |
| CLUE No. 6 | 1 |
| Procedural CLUE | 9 |

### Performance (11 marks)

(Please enter the appropriate mark in Space III)

Marks are awarded on the basis of the % error in the experimental data.

| Experimental Error | |
|---|---|
| >50% | 0 |
| 30-50% | 2 |
| 20-30% | 4 |
| 10-20% | 5 |
| 10% | 8 |
| Calculations | 3 |

**Experimental Design** ○ I

**Clues** ○ II

**Performance** ○ III

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# CLUE Model PROBLEM NO. 13

## I. INTRODUCTION

It is frequently necessary to identify the contents of a series of unlabelled bottles.

## II. SPECIAL LAB KIT

spot plates
test tubes
2 groups of dropper bottles labelled I, II, III and X,Y,Z
Bottles I, II, III - contain 0.5 mol/L solutions of
    sodium carbonate solution
    sodium chloride solution
    sodium acetate solution

Bottles X, Y, Z - contain 0.5 mol/L solutions of
    hydrochloric acid solution
    lead nitrate solution
    potassium nitrate solution

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to identify the contents of each of the 6 bottles.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design. Predict the observations you expect to make; explain how you will use these observations to identify the six solutions.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 4 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 5) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you will be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.....25)

| DESIGN (5 marks) | |
|---|---|
| NONE | 0 |
| FAULTY (requires an initial clue) | 2 |
| FAULTY (does not require an initial clue) | 3 |
| GOOD AND WORKABLE | 5 |

| CLUES (9 marks) |
|---|
| No. 1 ___(2) |
| No. 2 ___(2) |
| No. 3 ___(2) |
| No. 4 ___(2) |
| No. 5 ___(9) |

| PERFORMANCE (11 marks) | |
|---|---|
| 6 labels correct | 11 |
| 5 labels correct | 7 |
| 4 labels correct | 5 |
| 3 labels correct | 4 |
| 2 labels correct | 3 |
| 1 label correct | 1 |
| 0 labels correct | 0 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. CLUES

### Clue No. 1

1. The contents of bottles I, II and III will not show any visible reaction when mixed.

2. Prepare a "three by three" table of reaction possibilities.

### Clue No. 2

Effervescence is the sign of the production of a gas.

### Clue No. 3

The colour of a precipitate can often be a clue to its identity.

### Clue No. 4

Potassium and sodium compounds are generally very soluble in water.

### Procedural Clue Clue No.5)

1. Place a few drops of solutions I, II and III in separate test tubes (or in spot plate depressions).

2. Add a few drops of solution X to each of the solutions I, II and III.

3. To fresh samples of solutions I, II and III add samples of solution Y.

4. Repeat with solution Z.

5. Only one of solutions X, Y, and Z will produce a precipitate.

6. Only one of solutions X, Y, and Z will produce an effervescent reaction. The gas is carbon dioxide.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Change the coding for students who are not in the laboratory at the same time.

(b) Change the identity of the materials used.

(c) The concentrations of the acid and the carbonate must be checked to see if a visible effervescence can easily be observed.

# CLUE Model PROBLEM NO. 13

**Scoring Guide**

Student ____________________

Date ____________________

Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

| | | | |
|---|---|---|---|
| 1 | __________ | 6. | __________ |
| 2. | __________ | 7. | __________ |
| 3. | __________ | 8. | __________ |
| 4. | __________ | 9. | __________ |
| 5. | __________ | | __________ |

---

### For Teacher's Use Only

### Alternate Solution(s)

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution ☐ 5

### Experimental Design (5 marks)

(Please check the appropriate level and enter mark in Space I)

| | |
|---|---|
| None | ____ 0 |
| Faulty (requires an initial CLUE) | ____ 2 |
| Faulty (does not require an initial CLUE) | ____ 3 |
| Good and Workable | ____ 5 |

### Clues (9 marks)

(Please check the **CLUES** that were given to the student. Enter the net marks obtained by the student for **CLUES** in Space II)

Net Mark = 9 - (CLUES used)

| | |
|---|---|
| CLUE No. 1 | 2 |
| CLUE No. 2 | 2 |
| CLUE No. 3 | 2 |
| CLUE No. 4 | 2 |
| Procedural CLUE | 9 |

### Performance (11 marks)

(Please enter the appropriate mark in Space III)

| | |
|---|---|
| 6 labels correct | 11 |
| 5 labels correct | 7 |
| 4 labels correct | 5 |
| 3 labels correct | 4 |
| 2 labels correct | 3 |
| 1 label correct | 1 |
| 0 labels correct | 0 |

| Experimental Design | Clues | Performance |
|---|---|---|
| ○ I | ○ II | ○ III |

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# CLUE Model PROBLEM NO. 14

## I. INTRODUCTION

The chemist is frequently called upon to prepare and collect a given mass or volume of a pure substance.

## II. SPECIAL LAB KIT

balance
graduated pipet
medicine droppers
pipet bulbs
buret
graduated cylinder (250 mL)
bottle for the sodium hydroxide solution
hydrochloric acid solution (0.100 mol/L)
potassium hydroxide solution
sodium hydroxide solution
bromothymol blue solution
phenolphthalein solution
sodium hydrogen carbonate (s)

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to prepare 200 mL of sodium hydroxide solution containing 0.156 mol of sodium hydroxide per litre of solution.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 3 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 4) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you will be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.....25)

| DESIGN (5 marks) | |
|---|---|
| NONE | 0 |
| FAULTY (requires an initial clue) | 2 |
| FAULTY (does not require an initial clue) | 3 |
| GOOD AND WORKABLE | 5 |

| CLUES (9 marks) | |
|---|---|
| No. 1 ___ | (3) |
| No. 2 ___ | (2) |
| No. 3 ___ | (3) |
| No. 4 ___ | (9) |

PERFORMANCE (11 marks)

1. Marks are awarded on th basis of the % error i the experimental data.
2. Concentration of the sodium hydroxide solution.

| Experimental Error | |
|---|---|
| >20% | 0 |
| 10-20% | 1 |
| 5-10% | 3 |
| 1- 5% | 5 |
| < 2% | 8 |

3. Volume of solutions

| Experimental Error | |
|---|---|
| >10% | 0 |
| 5-10% | 1 |
| < 5% | 3 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. CLUES

### Clue No. 1

Determine the concentration of the sodium hydroxide solution.

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O$$

### Clue No. 2

Calculate the number of moles of NaOH in 200 mL of solution whose concentration is 0.156 mol/L.

### Clue No. 3

$$\text{Volume (L)} = \frac{\text{No. of moles required}}{\text{No. of mol/L}}$$

### Procedural Clue (Clue No. 4)

1. Use a pipet to transfer 10 mL of the given sodium hydroxide solution to an Erlenmeyer flask.
2. Add 3 drops of bromothymol blue solution to the sodium hydroxide solution.
3. Fill a buret with the hydrochloric acid solution.
4. Add hydrochloric acid until the bromothymol blue turns from blue to green.
5. Record the volume of hydrochloric acid solution consumed.
6. Calculate the concentration of the sodium hydroxide solution (mol/L).

NOTE: No. of moles of HCl = No. of moles of NaOH

7. Calculate the number of moles of sodium hydroxide in 200 mL of solution containing 0.156 mol of NaOH per litre of solution.
8. Calculate the volume ($V_1$) of the given sodium hydroxide solution which contains the number of moles calculated in 7.
9. Use a graduated pipet or cylinder to transfer $V_1$ mL of sodium hydroxide solution to a graduated cylinder.
10. Add sufficient distilled water to make the total volume 200 mL.
11. Transfer the NaOH solution from the graduated cylinder to the storage bottle.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) The sodium hydroxide solution can be replaced by potassium hydroxide for different classes or students.

(b) Make certain that all pipet work is done with pipet bulbs.

(c) The sodium hydroxide should contain approximately 1.5 mol (60 g) of sodium hydroxide per litre of solution. Provide 50 mL of solution in the SPECIAL LAB KIT.

(d) The concentration of the hydrochloric acid solution should be quoted to three significant digits (0.100 mol/L for example).

(e) Prepare solutions of varying concentrations for students who are in the laboratory at different times.

**CLUE Model PROBLEM NO. 14**

**Scoring Guide**

Student ____________________

Date ____________________

Score ____________________

**A. Experimental Design**
The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

**B. Observations**

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
6 ______________________
7 ______________________
8. ______________________
9 ______________________
______________________

---

**For Teacher's Use Only**

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution

☐ 5

**Experimental Design (5 marks)**

(Please check the appropriate level and enter mark in Space I)

| | | |
|---|---|---|
| None | ______ | 0 |
| Faulty (requires an initial CLUE) | ______ | 2 |
| Faulty (does not require an initial CLUE) | ______ | 3 |
| Good and Workable | ______ | 5 |

**Clues (9 marks)**

(Please check the CLUES that were given to the student. Enter the net marks obtained by the student for CLUES in Space II)

Net Mark = 9 - (CLUES used)

| | |
|---|---|
| CLUE No. 1 | 3 |
| CLUE No. 2 | 2 |
| CLUE No. 3 | 3 |
| Procedural CLUE | 9 |

**Performance (11 marks)**

(Please enter the appropriate mark in Space III)

Marks are awarded on the basis of the % error in the experimental data.

Concentration of the sodium hydroxide solution

Fxperimental Frror

| | |
|---|---|
| >20% | 0 |
| 10-20% | 1 |
| 5-10% | 3 |
| 1- 5% | 5 |
| < 2% | 8 |

Volume of solutions

Fxperimental Error

| | |
|---|---|
| >10% | 0 |
| 5-10% | 1 |
| < 5% | 3 |

**Experimental Design**

○ I

**Clues**

○ II

**Performance**

○ III

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# CLUE Model PROBLEM NO. 15

## I. INTRODUCTION

Many commericial medicinal tablets react with water to release gases. The identity of the gas can be determined and verified both qualitatively and quantitatively.

## II. SPECIAL LAB KIT

- wood splints
- thermometer
- serum cap
- syringe assembly
- graduated cylinder
- 2 commercial tablets
- calcium hydroxide solution
- barometer
- plastic bags
- rubber stoppers
- length of glass tubing

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to identify and determine the molecular weight of the gas produced when the commercial tablet is added to water.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 5 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 6) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.....25)

DESIGN (5 marks)

| | |
|---|---|
| NONE | 0 |
| FAULTY (requires an initial clue) | 2 |
| FAULTY (does not require an initial clue) | 3 |
| GOOD AND WORKABLE | 5 |

CLUES (9 marks)

No. 1 ___(3)

No. 2 ___(1)

No. 3 ___(1)

No. 4 ___(2)

No. 5 ___(1)

No. 6 ___(9)

PERFORMANCE (11 marks)

1. Identity of the gas ___3
2. Marks are awarded on th basis of the % error in the experimental data.

EXPERIMENTAL ERROR

| | |
|---|---|
| >60% | 0 |
| 40-60% | 2 |
| 20-40% | 4 |
| 10-20% | 5 |
| <10% | 6 |

3. Calculations

| | |
|---|---|
| Step 1 | 1 |
| Step 2 | 1 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. CLUES

### Clue No. 1

Samples of the gas can be tested with limewater (calcium hydroxide solution), a glowing splint and a burning splint.

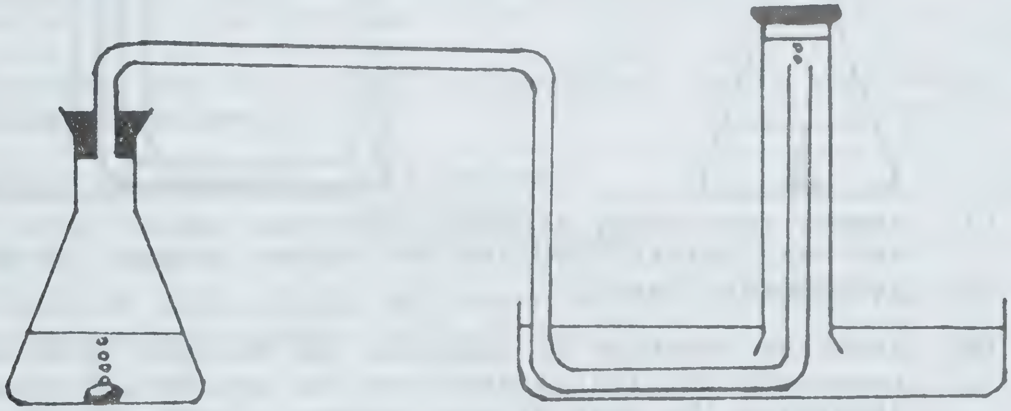
### Clue No. 2

The mass of one mole of the gas is the mass, at STP, of 22.4 L of the gas.

### Clue No. 3

The mass of the gas can be determined from the mass of the system before and after the reaction.

### Clue No. 4



### Clue No. 5

The vapour pressure of water will have an effect on the volume of gas collected.

Atmospheric pressure = gas pressure + vapour pressure of water

$$p_{Atm} = p_{gas} + p_{H_2O}$$

Procedural Clue (Clue No. 6)

(1) Break one tablet into 3 parts. Place each part into a separate test tube.

(2) Add water to the test tube.

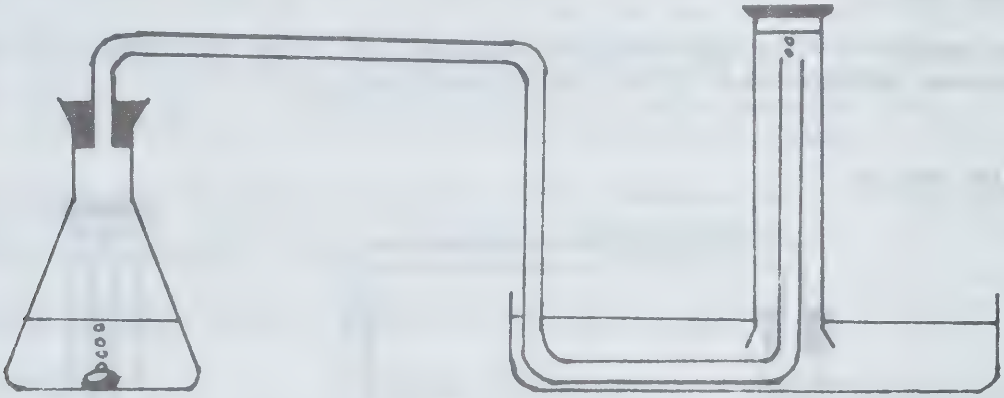
(3) Test the gas in the three test tubes with

a) a glowing splint
b) a burning splint
c) a tube of clear limewater

(4) Add 50 mL of water to an Erlenmeyer flask.

(5) Determine the mass of the Erlenmeyer flask, a one hole rubber stopper and a tablet.

(6) Assemble the apparatus as shown in the diagram.



(7) Remove the rubber stopper, drop the tablet into the water and very quickly replace the rubber stopper in the Erlenmeyer flask.

(8) When the reaction is complete (no further effervescence) remove the delivery tube from the one hole stopper and determine the mass of the stopper, flask and its contents.

(9) The mass and volume of the gas can now be compared.

(10) Measure the temperature of the water and atmospheric pressure.

(11) Pressure of the gas collected = $p_{gas}$

$$p_{gas} = P_{atm} - p_{water\ vapour}$$

(12) Convert the volume of the gas at the measured temperature and the partial pressure of the gas ($p_{gas}$) to STP.

(13) Calculate the mass of 22.4 L (1 mol) of the gas at STP.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) The tablet used may be any variety that reacts with water to liberate a gas.

(b) Examples of tablets: Alka Seltzer
Dentu Tabs
Calcium carbide

(c) The size of tablet must be chosen to satisfy the size of the available graduated cylinders.

**CLUE Model PROBLEM NO. 15**

**Scoring Guide**

Student ______________

Date ______________

Score ______________

**A. Experimental Design**
The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

**B. Observations**

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________ 6. ______________
2 ______________ 7 ______________
3. ______________ 8. ______________
4. ______________ 9. ______________
5. ______________ ______________

---

**For Teacher's Use Only**

**Alternate Solution(s)**
Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution. ☐ 5

**Experimental Design (5 marks)**
(Please check the appropriate level and enter mark in Space I)

| | |
|---|---|
| None | ____ 0 |
| Faulty (requires an initial CLUE) | ____ 2 |
| Faulty (does not require an initial CLUE) | ____ 3 |
| Good and Workable | ____ 5 |

**Clues (9 marks)**
(Please check the **CLUES** that were given to the student. Enter the net marks obtained by the student for **CLUES** in Space II)

Net Mark = 9 - (CLUES used)

| | |
|---|---|
| CLUE No. 1 | 3 |
| CLUE No. 2 | 1 |
| CLUE No. 3 | 1 |
| CLUE No. 4 | 2 |
| CLUE No. 5 | 1 |
| Procedural CLUE | 9 |

**Performance (11 marks)**
(Please enter the appropriate mark in Space III)

Identify of the gas ____ 3

Marks are awarded on the basis of the % error in the experimental data.

| EXPERIMENTAL ERROR | |
|---|---|
| >60% | 0 |
| 40-60% | 2 |
| 20-40% | 4 |
| 10-20% | 5 |
| <10% | 6 |

Calculations
Step 1 1
Step 2 1

**Experimental Design** ○ I

**Clues** ○ II

**Performance** ○ III

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# CLUE Model PROBLEM NO. 16

## I. INTRODUCTION

The labels (A,B,C and D) have come off a set of organic compounds. The identity of the compounds is necessary in order for the materials to be used in the laboratory.

## II. SPECIAL LAB KIT

capillary tubes
ice cubes
elastic bands
thermometer($-10^{\circ}$ - $110^{\circ}$C)
test tubes
mortar and pestle
set of organic compounds (A,B,C and D)

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to identify the set of organic compounds (A,B,C and D). In alphabetical order, the compounds are _____________,

_____________, _____________ and _____________.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 4 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 5) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.......25)

| DESIGN (5 marks) | | CLUES (9 marks) | PERFORMANCE (11 marks) | |
|---|---|---|---|---|
| NONE | 0 | No. 1 ___(2) | 4 labels correct | 11 |
| FAULTY (requires an initial clue) | 2 | No. 2 ___(2) | 3 labels correct | 7 |
| | | No. 3 ___(2) | 2 labels correct | 5 |
| FAULTY (does not require an initial clue) | 3 | No. 4 ___(2) | 1 label correct | 2 |
| GOOD AND WORKABLE | 5 | No. 5 ___(9) | 0 labels correct | 0 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

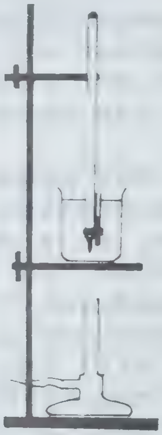
## VIII. CLUES

### Clue No. 1

Materials can be identified by a characteristic property such as melting point.

### Clue No. 2

Set up the apparatus as shown in the diagram.



### Clue No. 3

Melting points can be found in the Handbook of Chemistry and Physics.

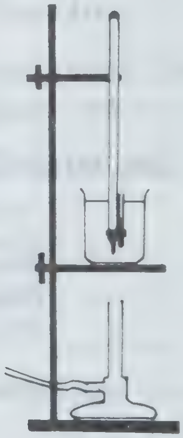
### Clue No. 4

________________ ____°C ________________ ____°C

________________ ____°C ________________ ____°C

### Procedural Clue (Clue No. 5)

1. Grind a sample of material A with a mortar and pestle.
2. Collect the sample in a capillary tube to a depth of 5 mm.
3. Use an elastic band to attach the capillary tube to the bulb of the thermometer.
4. Set up the apparatus as shown in the diagram.
5. Heat the water until the sample melts; observe the temperature at which melting occurs.
6. Repeat the procedure with B, C and D.



## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Select compounds with melting points between $40^{\circ}C$. and $85^{\circ}C$.

(b) Change the coding and samples for different students.

(c) List the compounds both by name and melting point.

(d) The compounds should differ in melting point by at least $5^{\circ}C$.

**CLUE Model PROBLEM NO. 16**

**Scoring Guide**

Student ______________

Date ______________

Score ______________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________

6. ______________________
7 ______________________
8 ______________________
9 ______________________
______________________

---

### For Teacher's Use Only

### Alternate Solution(s)

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

### Experimental Design (5 marks)

(Please check the appropriate level and enter mark in Space I)

| | | |
|---|---|---|
| None | ______ | 0 |
| Faulty (requires an initial CLUE) | ______ | 2 |
| Faulty (does not require an initial CLUE) | ______ | 3 |
| Good and Workable | ______ | 5 |

### Clues (9 marks)

(Please check the **CLUES** that were given to the student. Enter the net marks obtained by the student for **CLUES** in Space II)

Net Mark = 9 - (CLUES used)

CLUE No. 1 ____2____
CLUE No. 2 ____2____
CLUE No. 3 ____2____
CLUE No 4 ____2____

Procedural CLUE ____9____

### Performance (11 marks)

(Please enter the appropriate mark in Space III)

| | |
|---|---|
| 4 labels correct | 11 |
| 3 labels correct | 7 |
| 2 labels correct | 5 |
| 1 label correct | 2 |
| 0 labels correct | 0 |

**Experimental Design** ○ I

**Clues** ○ II

**Performance** ○ III

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# CLUE Model PROBLEM NO. 17

## I. INTRODUCTION

The labels (A,B,C and D) have come off a set of solid acids, each containing one mole of replaceable hydrogen per mole of compound.

## II. SPECIAL LAB KIT

buret
pipet
pipet bulb
sodium hydroxide solution (0.2 mol/L)
hydrochloric acid solution (0.2 mol/L)
phenolphthalein solution
bromothymol blue solution
litmus paper
unknown acid sample

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to identify the unknown acid. The unknown acid (a monobasic acid - one mole of replaceable hydrogen per mole of compound) is one of ____________, ____________,

____________ or ____________.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 6 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 7) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you will be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.....25)

| DESIGN (5 marks) | |
|---|---|
| NONE | 0 |
| FAULTY (requires an initial clue) | 2 |
| FAULTY (does not require an initial clue) | 3 |
| GOOD AND WORKABLE | 5 |

| CLUES (9 marks) | | |
|---|---|---|
| No. 1 | ___ | (2) |
| No. 2 | ___ | (2) |
| No. 3 | ___ | (1) |
| No. 4 | ___ | (1) |
| No. 5 | ___ | (1) |
| No. 6 | ___ | (1) |
| No. 7 | ___ | (9) |

**PERFORMANCE (11 marks)**

| | | |
|---|---|---|
| Identity of the unknown acid | ___ | 4 |
| Calculation | ___ | 2 |

Marks are awarded on the basis of the % error in the Experimental data.

| Experimental Error | | |
|---|---|---|
| >20% | ___ | 0 |
| 10-20% | ___ | 2 |
| 5-10% | ___ | 3 |
| 1-5% | ___ | 4 |
| <1% | ___ | 5 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. CLUES

### Clue No. 1

Acids can be identified by a characteristic property such as molar mass.

### Clue No. 2

Molar mass of an acid can be determined by titration with a base of known concentration.

### Clue No. 3

Use 1 g of the sample of the unknown acid.

### Clue No. 4

Each of the acids is monobasic.
No. of moles of acid = No. of moles of base

### Clue No. 5

$$\text{No. of moles of acid} = \frac{\text{Mass of acid}}{\text{molar mass}}$$

$$\text{No. of moles of base} = V_{(L)} \times \text{Concentration (mol/L)}$$

### Clue No. 6

Molar masses of the suggested acids are:

________________ _____g ________________ ______g

________________ ______g ________________ ______g

### Procedural Clue (Clue No. 7)

1. Find the mass of a sheet of "weighing paper".
2. Add a quantity of the unknown acid to the paper (about 1 g) and determine the mass of the paper and the unknown acid sample.
3. Add the acid to 25 mL of distilled water in an Erlenmeyer flask.
4. Shake to dissolve the acid.
5. Add 3 drops of phenolphthalein solution to the acid solution.
6. Fill a buret with sodium hydroxide solution (0.2 mol/L).
7. Add sodium hydroxide solution until the solution just turns pink.
8. Record the volume of sodium hydroxide solution required.
9. Calculate the number of moles of sodium hydroxide consumed.
10. No. of moles of acid = No. of moles of sodium hydroxide.
11. Calculate the mass of one mole of the unknown acid.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Select acids that are all monobasic (monoprotic).

(b) Select acids that are soluble in water.

(c) Select acids that differ in molar mass by at least 10%.

(d) In the PROBLEM section (III) list the acids both by name and by formula.

(e) Clue No. 6 - List the acids both by name and by formula.

(f) Some sample acids are:

benzoic acid
citric acid
oleic acid
stearic acid
potassium hydrogen carbonate
potassium hydrogen phthalate
potassium hydrogen tartrate
lauric acid

**CLUE Model PROBLEM NO. 17**

**Scoring Guide**

Student ______

Date ______

Score ______

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1 ______________________ 6 ______________________
2. ______________________ 7 ______________________
3. ______________________ 8 ______________________
4. ______________________ 9 ______________________
5. ______________________ ______________________

---

**For Teacher's Use Only**

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution. ☐ 5

**Experimental Design (5 marks)**

(Please check the appropriate level and enter mark in Space I)

| | | |
|---|---|---|
| None | ____ | 0 |
| Faulty (requires an initial CLUE) | ____ | 2 |
| Faulty (does not require an initial CLUE) | ____ | 3 |
| Good and Workable | ____ | 5 |

**Clues (9 marks)**

(Please check the **CLUES** that were given to the student. Enter the net marks obtained by the student for **CLUES** in Space II)

Net Mark = 9 - (CLUES used)

| | |
|---|---|
| CLUE No. 1 | 2 |
| CLUE No. 2 | 2 |
| CLUE No. 3 | 1 |
| CLUE No. 4 | 1 |
| CLUE No. 5 | 1 |
| CLUE No. 6 | 1 |
| Procedural CLUE | 9 |

**Performance (11 marks)**

(Please enter the appropriate mark in Space III)

Identity of the unknown acid ________ 4

Calculation ____ 2

Marks are awarded on the basis of the % error in the Experimental data.

Experimental Error

| | | |
|---|---|---|
| >20% | ____ | 0 |
| 10-20% | ____ | 2 |
| 5-10% | ____ | 3 |
| 1- 5% | ____ | 4 |
| < 1% | ____ | 5 |

**Experimental Design** ○ I

**Clues** ○ II

**Performance** ○ III

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# CLUE Model PROBLEM NO. 18

## I. INTRODUCTION

Pure substances and mixtures can be identified and distinguished by a study of their properties.

## II. SPECIAL LAB KIT

elastic bands
capillary tubes
ice cubes
test tubes
set of samples labelled A,B, C and D
mortar and pestle
thermometer
10 mm test tubes
scoopulas
spoons

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to identify the three pure substances and the mixture among the samples labelled A,B,C and D. In alphabetical order, the three pure substances are ____________,

____________ and ____________.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 5 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 6) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you will be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.....25)

| DESIGN (5 marks) | | CLUES (9 marks) | PERFORMANCE (11 marks) | |
|---|---|---|---|---|
| NONE | 0 | No. 1 ___(2) | Identity of mixture | __4 |
| FAULTY (requires an initial clue) | 2 | No. 2 ___(2) | 3 labels correct | ____7 |
| | | No. 3 ___(2) | 2 labels correct | ____4 |
| FAULTY (does not require an initial clue) | 3 | No. 4 ___(1) | 1 label correct | ____1 |
| GOOD AND WORKABLE | 5 | No. 5 ___(1) | 0 labels correct | ____0 |
| | | No. 6 ___(9) | | |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

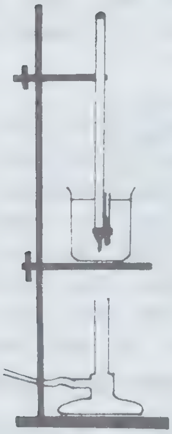
## VIII. CLUES

### Clue No. 1

The melting point of a pure substance is a characteristic property

### Clue No. 2

Set up the apparatus as shown in the diagram.



### Clue No. 3

A mixture does not melt at a fixed temperature.

### Clue No. 4

Melting points can be looked up in the Handbook of Chemistry and Physics.

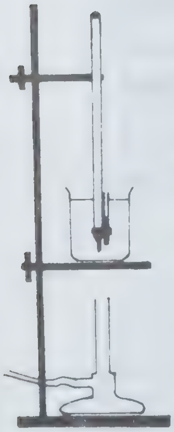
### Clue No. 5

Melting points:

_______________ ___°C _______________ ___°C

_______________ ___°C

### Procedural Clue (Clue No. 6)



1. Use a mortar and pestle to grind a sample of compound A.
2. Collect the sample in a capillary tube to a depth of 5 mm.
3. Use an elastic band to attach the capillary tube to the bulb of a thermometer.
4. Set up the apparatus as shown in the diagram.
5. Heat the water until the sample melts; observe the temperature at which melting occurs.
6. Repeat the procedure for samples B,C and D.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Select three (3) compounds with melting points between 40°C and 85°C.

(b) Change the coding and samples for different students.

(c) For the mixture select a pair of compounds with widely differing melting points. One of the compounds may have a melting point higher than 85°C.

(d) In the PROBLEM section (III) list the compounds both by name and by formula.

(e) Clue No. 5 - List the compounds both by name and formula.

(f) If Handbooks are not available provide the students with lists of compounds and melting points or a comparable set of data.

(g) Suggestions for substances to be used are:

| | |
|---|---|
| Naphthalene | (80°C) |
| Paradichlorobenzene | (53°C) |
| Thymol | (52°C) |
| Lauric Acid | (44°C) |

(h) For the mixture use naphthalene and another low melting solid.

**CLUE Model PROBLEM NO. 18**

**Scoring Guide**

Student

Date

Score

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________________ 6 ______________________
2. ______________________ 7 ______________________
3. ______________________ 8 ______________________
4. ______________________ 9 ______________________
5. ______________________ ______________________

---

## For Teacher's Use Only

### Alternate Solution(s)

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution. ☐ 5

### Experimental Design (5 marks)

(Please check the appropriate level and enter mark in Space I)

| | | |
|---|---|---|
| None | ______ | 0 |
| Faulty (requires an initial CLUE) | ______ | 2 |
| Faulty (does not require an initial CLUE) | ______ | 3 |
| Good and Workable | ______ | 5 |

### Clues (9 marks)

(Please check the **CLUES** that were given to the student. Enter the net marks obtained by the student for **CLUES** in Space II)

Net Mark = 9 - (CLUES used)

| | |
|---|---|
| CLUE No. 1 | 2 |
| CLUE No. 2 | 2 |
| CLUE No. 3 | 2 |
| CLUE No. 4 | 1 |
| CLUE No. 5 | 1 |
| Procedural CLUE | 9 |

### Performance (11 marks)

(Please enter the appropriate mark in Space III)

| | | |
|---|---|---|
| Identity of mixture | ______ | 4 |
| 3 labels correct | ______ | 7 |
| 2 labels correct | ______ | 4 |
| 1 label correct | ______ | 1 |
| 0 labels correct | ______ | 0 |

**Experimental Design** ○ I

**Clues** ○ II

**Performance** ○ III

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# CLUE Model PROBLEM NO. 19

## I. INTRODUCTION

An alloy is a solid mixture of two or more metals; the composition of the alloy can be determined in a variety of ways.

## II. SPECIAL LAB KIT

Na-Pb alloy sample
gas measuring tube
hydrochloric acid solution (0.2 mol/L)
plastic syringe
oven
overflow can
tweezers
barometer

CAUTION
DO NOT HANDLE THE
ALLOY WITH YOUR HANDS

bromothymol blue solution
filter paper
funnel

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to determine the composition (percent by mass) of the Na-Pb (sodium-lead) alloy. Before completing your design put 5 mL water and/or dilute hydrochloric acid in a small test tube. Add a sample of the alloy to the water/acid in the test tube.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 3 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 4) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you will be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.....25)

| DESIGN (5 marks) | |
|---|---|
| NONE | 0 |
| FAULTY (requires an initial clue) | 2 |
| FAULTY (does not require an initial clue) | 3 |
| GOOD AND WORKABLE | 5 |

| CLUES (9 marks) | | |
|---|---|---|
| No. 1 | ___ | (3) |
| No. 2 | ___ | (2) |
| No. 3 | ___ | (3) |
| No. 4 | ___ | (9) |

| PERFORMANCE (11 marks) | | |
|---|---|---|
| Experimental Error | | |
| > 50% | ___ | 0 |
| 40 - 50% | ___ | 3 |
| 30 - 40% | ___ | 5 |
| 20 - 30% | ___ | 6 |
| 10 - 20% | ___ | 8 |
| 5 - 10% | ___ | 10 |
| 0 - 5% | ___ | 11 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. CLUES

### Clue No. 1

a) $2Na(s) + 2H_2O \rightarrow 2NaOH(aq) + H_2(g)$

b) The volume of hydrogen gas released and/or the quantity of sodium hydroxide produced can be used to calculate the % composition, by mass, of the alloy.

### Clue No. 2

a) Collect the hydrogen gas and record the volume, temperature and pressure of the gas.

b) Titrate the sodium hydroxide with the hydrochloric acid solution.

### Clue No. 3

a) From the balanced equation (alloy + water):

1 mol of hydrogen gas is produced by the reaction of 2 mol of sodium with water.

$$\text{No. of moles of hydrogen} = V(STP) \times \frac{1}{22.4} = n \text{ moles}$$

$$\text{No. of moles of sodium} = 2n \text{ mol}$$

$$\%\text{ sodium in the alloy} = \frac{23 \times 2n}{\text{mass of alloy}} \times 100\%$$

b) From the balanced equation (alloy + water):
1 mol of sodium hydroxide is produced by the reaction of 1 mol of sodium with water.

From the balanced neutralization equation:

$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O$$

1 mol of NaOH is neutralized by 1 mol HCl

$$\text{No. of moles of HCl} = V_{(L)} \times \text{Concentration (mol/L)}$$
$$= n \text{ moles}$$

$$\text{No. of moles of sodium hydroxide} = n \text{ moles}$$

$$\text{No. of moles of sodium} = n \text{ moles}$$

$$\%\text{ sodium in the alloy} = \frac{23 \times n}{\text{Mass of alloy}} \times 100\%$$

Procedural Clue (Clue No. 4)

1. Find the mass of a piece of "weighing" paper.
2. Select 3 granules of the alloy and determine the total mass of the paper and the alloy.
3. Calculate the mass of the alloy.
4. Place the sample of the alloy in a beaker containing 50 mL of distilled water and 3 drops of bromothymol blue solution.
5. Fill a buret with hydrochloric acid solution (0.2 mol/L)
6. Titrate (add dropwise) the hydrochloric acid into the alloy solution until the solution turns green.
7. Record the volume of hydrochloric acid consumed.
8. Calculate the number of moles of hydrochloric acid consumed

   No. of moles of HCl = $V_{(L)}$ X Concentration (mol/L)

   No. of moles of NaOH = No. of moles of HCl

   No. of moles of Na = No. of moles of NaOH
9. Mass of Na in the original sample

   = 23 x No. of moles of sodium (g)
10. % (by mass) of sodium in the original sample

$$= \frac{\text{mass of sodium}}{\text{mass of alloy}} \times 100\%$$

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a) Titration
  1) Mass of alloy sample
  2) Reaction of alloy with water
  3) Titration and calculation of % sodium

(b) Gas Collection
  1) Mass of alloy sample
  2) Reaction of alloy with water
  3) Collection of gas and calculation of % sodium

(c) Filtration - this method does not give accurate results
  1) Mass of alloy sample
  2) Reaction of alloy with water
  3) Filtration and mass of lead
  4) Calculation of % sodium

(d) Mass of Sodium Hydroxide
  1) Mass of alloy sample
  2) Reaction of alloy with water
  3) Filtration, evaporation and mass of sodium hydroxide
  4) Calculation of % sodium

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) The alloy is manufactured by J.T. Baker Chemicals - No. 1 - 9413
The alloy is available from Canlab at approximately $9.00 per lb
(b) The alloy is approximately 10% sodium, by mass.
(c) Keep the alloy dry until it is being used.
(d) The students must be cautioned not to handle the alloy with thei hands. This is an extra precaution - the alloy appears to be easy to handle. The alloy does not react rapidly or vigorously with water. The alloy sinks to the bottom of the beaker and reacts slowly with the water.
(e) As an added safety precaution ALL students MUST be advised to wear Safety Glasses.

**CLUE Model PROBLEM NO. 19**

**Scoring Guide**

Student ____________________

Date ____________________

Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ____________________
2. ____________________
3 ____________________
4. ____________________
5 ____________________
6. ____________________
7. ____________________
8 ____________________
9. ____________________
____________________

---

### For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution. ☐ 5

**Experimental Design (5 marks)**

(Please check the appropriate level and enter mark in Space I)

| | |
|---|---|
| None | ____ 0 |
| Faulty (requires an initial CLUE) | ____ 2 |
| Faulty (does not require an initial CLUE) | ____ 3 |
| Good and Workable | ____ 5 |

**Clues (9 marks)**

(Please check the **CLUES** that were given to the student. Enter the net marks obtained by the student for **CLUES** in Space II)

Net Mark = 9 - (CLUES used)

| | |
|---|---|
| CLUE No. 1 | 3 |
| CLUE No. 2 | 2 |
| CLUE No. 3 | 3 |
| Procedural CLUE | 9 |

**Performance (11 marks)**

(Please enter the appropriate mark in Space III)

Experimental Error

| | |
|---|---|
| >50% | ____ 0 |
| 40 - 50% | ____ 3 |
| 30 - 40% | ____ 5 |
| 20 - 30% | ____ 6 |
| 10 - 20% | ____ 8 |
| 5 - 10% | ____ 10 |
| 0 - 5% | ____ 11 |

**Experimental Design** ○ I

**Clues** ○ II

**Performance** ○ III

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# CLUE Model PROBLEM NO. 20

## I. INTRODUCTION

The medical "cold pack" operates on the principle that various salts absorb heat when they dissolve in water.

## II. SPECIAL LAB KIT

thermometer
styrofoam cup
balance
unknown salt sample
graduated cylinder (100 mL)
paper squares for use on the balance

Data:
The heat absorbed per gram of substance dissolving (heat of solution) in joules per gram:

| | | | |
|---|---|---|---|
| 1) | ammonium chloride | $NH_4Cl$ | 277 J/g |
| 2) | ammonium perchlorate | $NH_4ClO_4$ | 154 J/g |
| 3) | potassium chloride | KCl | 231 J/g |
| 4) | potassium nitrate | $KNO_3$ | 346 J/g |
| 5) | sodium acetate trihydrate | $NaCH_3COO \cdot 3H_2O$ | 145 J/g |

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to identify the unknown salt sample. The unknown is one of the salts listed in the "Data" above.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 3 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 4) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you will be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.....25)

DESIGN (5 marks)

| | |
|---|---|
| NONE | 0 |
| FAULTY (requires an initial clue) | 2 |
| FAULTY (does not require an initial clue) | 3 |
| GOOD AND WORKABLE | 5 |

CLUES (9 marks)

No. 1 ___(2)

No. 2 ___(3)

No. 3 ___(3)

No. 4 ___(9)

PERFORMANCE (11 marks)

| | |
|---|---|
| Identity of the salt | _____2 |
| Experimental Error | |
| >50% | _________0 |
| 30-50% | _________4 |
| 20-30% | _________6 |
| 10-20% | _________8 |
| 0-10% | _________9 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. CLUES

### Clue No. 1

The heat of dissolving is the amount of heat absorbed when one gram of substance dissolves in water. This quantity is expressed in J/g.

### Clue No. 2

4.2 J is the amount of heat required to raise or lower the temperature of one gram of water through one Celsius degree.

### Clue No. 3

The amount of heat absorbed per gram is calculated as follows:

No. of joules =

$$\frac{\text{Mass of water (g)} \times \text{Temperature drop } (^{\circ}\text{C}) \times 4.2\ (\text{J}/^{\circ}\text{C}\cdot\text{g})}{\text{Mass of salt (g)}}$$

NOTE: One gram of water occupies very close to one millilitre. You may assume that the dissolving of the salt will not affect the heat capacity of water.

### Procedural Clue (Clue No. 4)

1. Find the mass of the sample using the balance.
2. Measure 100 mL of water using the graduated cylinder. Pour the water into the styrofoam cup and measure its temperature.
3. Add the salt to the water in the styrofoam cup and stir until all is dissolved; you may use the thermometer as a stirring rod if you stir very carefully.
4. Record the lowest temperature reached by the solution.
5. Calculate the quantity of heat absorbed by the salt-water system.
6. Divide the quantity of heat absorbed by the number of grams of salt used.
7. Compare this answer to the values provided under "data". The closest value identifies the unknown salt.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) $KNO_3$ and $NH_4Cl$ give good results; they should be ground in a mortar to get a finer sample. This speeds up dissolving and reduces error.

(b) Provide each student with about 10 g of the salt sample.

(c) Be careful that you do not use hydrated forms of the salts.

(d) The other salts are either hard to obtain or have low solubilities. They are added to the list as distractors.

(e) Problem No. 21 is similar to Problem No. 20, but the data is quoted in kJ/mol in Problem No. 21.

**CLUE Model PROBLEM NO. 20**

**Scoring Guide**

Student ______

Date ______

Score ______

**A. Experimental Design**

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

**B. Observations**

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
6. ______________________
7 ______________________
8 ______________________
9 ______________________
______________________

---

## For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

**Experimental Design (5 marks)**

(Please check the appropriate level and enter mark in Space I)

None ______ 0
Faulty (requires an initial CLUE) ______ 2
Faulty (does not require an initial CLUE) ______ 3
Good and Workable ______ 5

**Clues (9 marks)**

(Please check the **CLUES** that were given to the student. Enter the net marks obtained by the student for **CLUES** in Space II)

Net Mark = 9 - (CLUES used)

CLUE No. 1 ___2___
CLUE No. 2 ___3___
CLUE No. 3 ___3___

Procedural CLUE ___9___

**Performance (11 marks)**

(Please enter the appropriate mark in Space III)

Identity of the salt ______ 2

Experimental Error

>50% ______ 0
30-50% ______ 4
20-30% ______ 6
10-20% ______ 8
0-10% ______ 9

**Experimental Design** ○ I

**Clues** ○ II

**Performance** ○ III

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# CLUE Model PROBLEM NO. 21

## . INTRODUCTION

The medical "cold pack" operates on the principle that various salts absorb heat when they dissolve in water.

## I. SPECIAL LAB KIT

thermometer
styrofoam cup
balance
unknown salt sample
graduated cylinder (100 mL)
paper squares for use on the balance

Data:
The heat absorbed per mole of substance dissolving (heat of solution) in kJ/mole:

| | | | |
|---|---|---|---|
| 1) | ammonium chloride | $NH_4Cl$ | 14.8 kJ/mol |
| 2) | ammonium perchlorate | $NH_4ClO_4$ | 18.0 kJ/mol |
| 3) | potassium chloride | $KCl$ | 17.2 kJ/mol |
| 4) | potassium nitrate | $KNO_3$ | 34.6 kJ/mol |
| 5) | sodium acetate trihydrate | $NaCH_3COO \cdot 3H_2O$ | 19.7 kJ/mol |

## II. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to identify the unknown salt sample. The unknown is one of the salts listed in the "Data" above.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 5 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 6) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you will be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.....25)

| DESIGN (5 marks) | | CLUES (9 marks) | PERFORMANCE (11 marks) |
|---|---|---|---|
| NONE | 0 | No. 1 ___(2) | Identity of the salt___ |
| FAULTY (requires an initial clue) | 2 | No. 2 ___(1) | |
| | | No. 3 ___(2) | Experimental Error |
| FAULTY (does not require an initial clue) | 3 | No. 4 ___(1) | >50% ______ |
| | | | 30-50% ______ |
| GOOD AND WORKABLE | 5 | No. 5 ___(2) | 20-30% ______ |
| | | | 10-20% ______ |
| | | No. 6 ___(9) | 0-10% ______ |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. CLUES

### Clue No. 1

The heat of dissolving is the amount of heat absorbed when one gram of substance dissolves in water. This quantity is expressed in kJ/mole.

### Clue No. 2

4.2 J is the amount of heat required to raise or lower the temperature of one gram of water through one Celsius degree.

### Clue No. 3

The amount of heat absorbed per gram is calculated as follows:

$$\text{No. of joules} = \frac{\text{Mass of water (g)} \times \text{Temperature drop } (^{\circ}\text{C}) \times 4.2\ (\text{J}/^{\circ}\text{C}\cdot\text{g})}{\text{Mass of salt}}$$

NOTE: One gram of water occupies very close to one millilitre. You may assume that the dissolving of the salt will not affect the heat capacity of water.

### Clue No. 4

$$\text{No. of kJ} = \frac{\text{No. of J}}{1000}$$

### Clue No. 5

$$\text{No. of kJ/mol} = \frac{\text{No. of kJ}}{\text{Molar mass}}$$

### Procedural Clue (Clue No. 6)

1. Find the mass of the sample using the balance.
2. Measure 100 mL of water using the graduated cylinder. Pour the water into the styrofoam cup and measure its temperature.
3. Add the salt to the water in the styrofoam cup and stir until all is dissolved;you may use the thermometer as a stirring rod if you stir very carefully.
4. Record the lowest temperature reached by the solution.
5. Calculate the quantity of heat absorbed by the salt-water system.
6. Calculate the quantity of heat absorbed in kJ/mol.
7. Compare this answer to the values provided under "data". The closest value identifies the unknown salt.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) $KNO_3$ and $NH_4Cl$ give good results; they should be ground in a mortar to get a finer sample. This speed up dissolving and reduces error.

(b) Provide each student with about 10 g of the salt sample.

(c) Be careful that you do not use hydrated forms of the salts.

(d) The other salts are either hard to obtain or have low solubilities. They are added to the list as distractors.

(e) Problem No. 21 is similar to Problem No. 20, but data is quoted in J/g in Problem No. 20.

# CLUE Model PROBLEM NO. 21

**Scoring Guide**

Student ____________________

Date ____________________

Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
6 ______________________
7. ______________________
8 ______________________
9. ______________________
______________________

---

## For Teacher's Use Only

### Alternate Solution(s)

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

### Experimental Design (5 marks)

(Please check the appropriate level and enter mark in Space I)

| | | |
|---|---|---|
| None | ______ | 0 |
| Faulty (requires an initial CLUE) | ______ | 2 |
| Faulty (does not require an initial CLUE) | ______ | 3 |
| Good and Workable | ______ | 5 |

### Clues (9 marks)

(Please check the **CLUES** that were given to the student. Enter the net marks obtained by the student for **CLUES** in Space II)

Net Mark = 9 - (CLUES used)

| | |
|---|---|
| CLUE No. 1 | 2 |
| CLUE No. 2 | 1 |
| CLUE No. 3 | 2 |
| CLUE No. 4 | 1 |
| CLUE No. 5 | 2 |
| Procedural CLUE | 9 |

### Performance (11 marks)

(Please enter the appropriate mark in Space III)

Identity of the salt ____

Experimental Error

| | | |
|---|---|---|
| >50% | ______ | 0 |
| 30-50% | ______ | 4 |
| 20-30% | ______ | 6 |
| 10-20% | ______ | 8 |
| 0-10% | ______ | 9 |

**Experimental Design** ○ I

**Clues** ○ II

**Performance** ○ III

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# CLUE Model PROBLEM NO. 22

## I. INTRODUCTION

The density of a gas can be used to identify the gas; density is a characteristic property of all materials.

## II. SPECIAL LAB KIT

alka seltzer tablet
flask
delivery tube
graduated cylinder
splints
syringe (50 mL)
nichrome or copper wire loops
saturated barium hydroxide solution
saturated calcium hydroxide solution

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to determine the density of the gas produced when an Alka Seltzer tablet is added to water.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 4 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 5) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you will be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.....25)

| DESIGN (5 marks) | |
|---|---|
| NONE | 0 |
| FAULTY (requires an initial clue) | 2 |
| FAULTY (does not require an initial clue) | 3 |
| GOOD AND WORKABLE | 5 |

| CLUES (9 marks) | |
|---|---|
| No. 1 | ___(2) |
| No. 2 | ___(1) |
| No. 3 | ___(2) |
| No. 4 | ___(3) |
| No. 5 | ___(9) |

| PERFORMANCE (11 marks) | | |
|---|---|---|
| Identity of gas | ____ | 3 |
| Choice of units | ____ | 1 |
| Experimental Error | | |
| >40% | ____ | 0 |
| 30-40% | ____ | 1 |
| 20-30% | ____ | 2 |
| 10-20% | ____ | 4 |
| 5-10% | ____ | 5 |
| < 5% | ____ | 7 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. CLUES

### Clue No. 1

The effervescent gas can be tested with a glowing splint, a burning splint, saturated barium hydroxide solution and/or saturated calcium hydroxide solution.

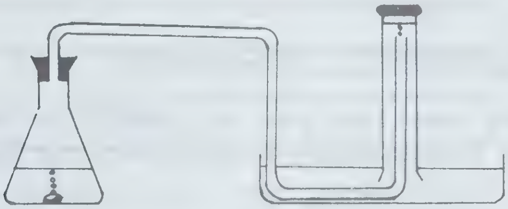
### Clue No. 2

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

### Clue No. 3

The mass of the gas can be calculated by comparing the mass of the reagents before and after the reaction.

### Clue No. 4



### Procedural Clue (Clue No. 5)

1. Break an Alka Seltzer tablet into pieces.

2. Place chips of the tablet in water and test the effervescent gas with a glowing splint and a burning splint. Test the gas with drops or films of saturated barium hydroxide and/or calcium hydroxide solutions.

3. Place 50 mL of water in a flask; stopper the flask.

4. Determine the mass of the stoppered flask and a piece of the Alka Seltzer tablet.

5. Set up the aparatus as shown in the diagram. Remove the stopper, add the piece of Alka Seltzer tablet and quickly restopper the flask.

6. When the reaction ceases measure the volume of gas collected, the temperature of the water and then remove the delivery tube from the reaction flask.

7. Determine the mass of the reaction flask.

8. Calculate the mass of the gas collected.

9. Calculate the density of the gas collected.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Prepare copper or nichrome wire loops that can be used for the $CO_2(g)$ test.

(b) The loop when dipped in $Ba(OH)_2(aq)$ or in $Ca(OH)_2(aq)$ will produce a film of the solution. The film when placed in contact with bubbles of $CO_2(g)$ will turn milky very quickly.

(c) Prepare graduated cylinders which are large enough to accommodate the gas from half an Alka Seltzer tablet.

(d) Try antacids other than Alka Seltzer.

Some examples are

(i) Bromoseltzer

(ii) Bicarbonate of soda

**CLUE Model PROBLEM NO. 22**

## Scoring Guide

Student ____________________

Date ____________________

Score ____________________

### A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

### B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5 ______________________
6. ______________________
7. ______________________
8. ______________________
9. ______________________

______________________

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### For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

**Experimental Design (5 marks)**

(Please check the appropriate level and enter mark in Space I)

| | | |
|---|---|---|
| None | ______ | 0 |
| Faulty (requires an initial CLUE) | ______ | 2 |
| Faulty (does not require an initial CLUE) | ______ | 3 |
| Good and Workable | ______ | 5 |

**Clues (9 marks)**

(Please check the CLUES that were given to the student. Enter the net marks obtained by the student for CLUES in Space II)

Net Mark = 9 - (CLUES used)

| | |
|---|---|
| CLUE No. 1 | 2 |
| CLUE No. 2 | 1 |
| CLUE No. 3 | 2 |
| CLUE No. 4 | 3 |
| Procedural CLUE | 9 |

**Performance (11 marks)**

(Please enter the appropriate mark in Space III)

| | | |
|---|---|---|
| Identity of gas | ______ | 3 |
| Choice of units | ______ | 1 |

Experimental Error

| | | |
|---|---|---|
| >40% | ______ | 0 |
| 30-40% | ______ | 1 |
| 20-30% | ______ | 2 |
| 10-20% | ______ | 4 |
| 5-10% | ______ | 5 |
| < 5% | ______ | 7 |

**Experimental Design** ○ I

**Clues** ○ II

**Performance** ○ III

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# CLUE Model PROBLEM NO. 23

## I. INTRODUCTION

Product X neutralizes 36 times its own "weight" in excess stomach juices. There are many antacids on the market. Some are more effective than others.

## II. SPECIAL LAB KIT

buret
pipet
eye dropper
graduated cylinder

sodium hydroxide solution (0.2 mol/L)
hydrochloric acid solution (0.2 mol/L)
phenolphthalein solution
bromothymol blue solution
tablets of 2 or 3 different antacids

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to determine which of the 2 antacid tablets in your kit is the "best" antacid. Express your answer in moles of acid consumed per tablet.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 4 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 5) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.....25)

DESIGN (5 marks)

| | |
|---|---|
| NONE | 0 |
| FAULTY (requires an initial clue) | 2 |
| FAULTY (does not require an initial clue) | 3 |
| GOOD AND WORKABLE | 5 |

CLUES (9 marks)

| | | |
|---|---|---|
| No. 1 | ____ | (2) |
| No. 2 | ____ | (1) |
| No. 3 | ____ | (3) |
| No. 4 | ____ | (2) |
| No. 5 | ____ | (9) |

PERFORMANCE (11 marks)

| | | |
|---|---|---|
| Best Antacid | ____ | 3 |
| Calculations | ____ | 2 |
| Experimental Error | | |
| Tablet 1 | | |
| >10% | ____ | 0 |
| 5 -10% | ____ | 1 |
| 2 - 5% | ____ | 2 |
| 0 - 2% | ____ | 3 |
| Tablet 2 | | |
| >10% | ____ | 0 |
| 5 -10% | ____ | 1 |
| 2 - 5% | ____ | 2 |
| 0 - 2% | ____ | 3 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. CLUES

### Clue No. 1

The antacid tablet is a base; it neutralizes excess stomach acids.

### Clue No. 2

The tablet dissolves slowly in water.

### Clue No. 3

The effectiveness of the antacid is related to the quantity of acid required to neutralize a tablet.

### Clue No. 4

The "best" antacid refers to the most effective tablet; the one which neutralizes the greatest volume (no. of moles) of acid solution.

### Procedural Clue (Clue No. 5)

1. Dissolve tablet 1 in 50 mL of water in an Erlenmeyer flask.
2. Add 3 drops of phenolphthalein solution to the antacid solution.
3. Fill a buret with the hydrochloric acid solution.
4. Add the hydrochloric acid solution to the antacid until the solution turns colourless.
5. Calculate the quantity (no. of mol) of hydrochloric acid required to neutralize the antacid.
6. Repeat the procedure(s) with tablet 2.
7. Select the "best" antacid tablet.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) A variety of antacids are available for study.

(b) Provide students with different antacids - coded appropriately.

(c) In the commercial - "36 times its weight in excess stomach acidity" refers to the "weight" of the acid solution (including the aqueous component of the solution).

(d) Some commercial antacids that can be used are:

- (i) Alka Seltzer
- (ii) Maalox
- (iii) Tums
- (iv) Rolaids

**CLUE Model PROBLEM NO. 23**

## Scoring Guide

Student ____________________

Date ____________________

Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
6. ______________________
7. ______________________
8. ______________________
9. ______________________

______________________

---

## For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

**Experimental Design (5 marks)**

(Please check the appropriate level and enter mark in Space I)

| | | |
|---|---|---|
| None | ______ | 0 |
| Faulty (requires an initial CLUE) | ______ | 2 |
| Faulty (does not require an initial CLUE) | ______ | 3 |
| Good and Workable | ______ | 5 |

**Clues (9 marks)**

(Please check the **CLUES** that were given to the student. Enter the net marks obtained by the student for **CLUES** in Space II)

Net Mark = 9 - (CLUES used)

| | |
|---|---|
| CLUE No. 1 | 2 |
| CLUE No. 2 | 1 |
| CLUE No. 3 | 3 |
| CLUE No. 4 | 2 |
| Procedural CLUE | 9 |

**Performance (11 marks)**

(Please enter the appropriate mark in Space III)

| | | |
|---|---|---|
| Best Antacid | ______ | 3 |
| Calculations | ______ | 2 |

Experimental Error

Tablet 1

| | | |
|---|---|---|
| >10% | ______ | 0 |
| 5 -10% | ______ | 1 |
| 2 - 5% | ______ | 2 |
| 0 - 2% | ______ | 3 |

Tablet 2

| | | |
|---|---|---|
| >10% | ______ | 0 |
| 5 -10% | ______ | 1 |
| 2 - 5% | ______ | 2 |
| 0 - 2% | ______ | 3 |

**Experimental Design** ○ I

**Clues** ○ II

**Performance** ○ III

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# CLUE Model PROBLEM NO. 24

## I. INTRODUCTION

Mass determinations and calculations can be performed without the use of a balance.

## II. SPECIAL LAB KIT

magnesium ribbon (prepared sample)
graduate cylinder (100 mL, 250 mL)
hydrochloric acid solution (6 mol/L)
glass tray
copper wire
thermometer
barometer
syringe (50 mL)
emery paper

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to determine the mass of the sample of magnesium ribbon provided to you. *YOU MAY NOT USE A BALANCE*

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 4 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 6) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you will be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.....25)

| DESIGN (5 marks) | | CLUES (9 marks) | PERFORMANCE (11 marks) | |
|---|---|---|---|---|
| NONE | 0 | No. 1 ___(1) | Calculations ____ | 4 |
| FAULTY (requires an initial clue) | 2 | No. 2 ___(2) | Experimental Error | |
| | | No. 3 ___(2) | >35% ____ | 0 |
| FAULTY (does not require an initial clue) | 3 | | 20-35% ____ | 2 |
| | | No. 4 ___(1) | 10-20% ____ | 4 |
| | | | 5-10% ____ | 6 |
| GOOD AND WORKABLE | 5 | No. 5 ___(2) | < 5% ____ | 7 |
| | | No. 6 ___(9) | | |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

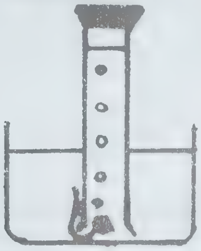
SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. CLUES

### Clue No. 1

Magnesium reacts with hydrochloric acid to produce magnesium chloride (aq) and hydrogen gas.

### Clue No. 2



### Clue No. 3

$p_{H_2} = P_{Atm} - p_{H_2O}$

### Clue No. 4

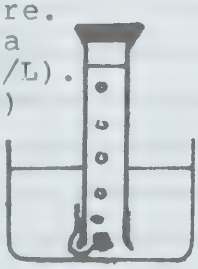
One mole of hydrogen gas at STP occupies 22.4 L.
$PV = n R T$

### Clue No. 5

$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

### Procedural Clue (Clue No. 6)

1. Select a sample of magnesium ribbon and fold it into a small rectangular package.
2. Wrap the magnesium package with a length of copper wire.
3. Fill a gas measuring tube (or graduated cylinder) to a depth of 10 cm with hydrochloric acid solution (6 mol/L).
4. Carefully fill the gas measuring tube (to overflowing) with water.
5. Cover the gas measuring tube with a square of paper. Invert the tube into a tray of water.
6. Set up the apparatus as shown in the diagram.
7. Measure and record the volume of gas collected.
8. Measure and record the temperature of the water.
9. Measure and record the atmospheric pressure.
10. Calculate the partial pressure of hydrogen ($p_{H_2}$)
    $p_{H_2} = P_{Atm} - p_{H_2O}$
11. $PV = n R T$
12. $Mg(s) + 2HCl(aq) \rightarrow MgCl(aq) + H_2(g)$
    Calculate the mass of magnesium consumed.



## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Determine the mass of a 1 m length of Mg ribbon; provide the students with the mass/metre of Mg ribbon.

(b) Select lengths of Mg ribbon which will produce the volume of hydrogen, $H_2$, that fits the volume of the gas collection container.

(c) Lengths of glass tubing can be converted to gas measuring tubes by gluing a scale onto the tube and stoppering one end of the tube.

**CLUE Model PROBLEM NO. 24**

**Scoring Guide**

Student ______________________

Date ______________________

Score ______________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________________
2. ______________________
3 ______________________
4. ______________________
5. ______________________
6. ______________________
7. ______________________
8 ______________________
9. ______________________
______________________

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### For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

**Experimental Design (5 marks)**

(Please check the appropriate level and enter mark in Space I)

| | | |
|---|---|---|
| None | ______ | 0 |
| Faulty (requires an initial CLUE) | ______ | 2 |
| Faulty (does not require an initial CLUE) | ______ | 3 |
| Good and Workable | ______ | 5 |

**Clues (9 marks)**

(Please check the **CLUES** that were given to the student. Enter the net marks obtained by the student for **CLUES** in Space II)

Net Mark = 9 - (CLUES used)

| | |
|---|---|
| CLUE No. 1 | 1 |
| CLUE No. 2 | 2 |
| CLUE No. 3 | 2 |
| CLUE No. 4 | 1 |
| CLUE No. 5 | 2 |
| Procedural CLUE | 9 |

**Performance (11 marks)**

(Please enter the appropriate mark in Space III)

| | | |
|---|---|---|
| Calculations | ______ | 4 |
| Experimental Error | | |
| >35% | ______ | 0 |
| 20-35% | ______ | 2 |
| 10-20% | ______ | 4 |
| 5-10% | ______ | 6 |
| < 5% | ______ | 7 |

**Experimental Design** ○ I

**Clues** ○ II

**Performance** ○ III

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**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# CLUE Model PROBLEM NO. 25

## I. INTRODUCTION

So far in your study of chemistry you have looked at and worked with many different substances. You must have observed that many substances dissolve in water and that some of these soluble substances produce coloured solutions.

## II. SPECIAL LAB KIT

beakers
eye droppers
light source
pipets
flasks
Cobalt(II) chloride hexahydrate
graduated cylinders
test tubes (uniform size)
balances (centigram)
2 unknown solutions (labelled A and B) whose concentrations are less than 1.0 mol/L

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to determine the the concentrations of two solutions of cobalt chloride of unknown concentration.

DATA:

(a) The solubility of cobalt(II) chloride is approximately 50 g per 100 g of water at room temperature.
(b) The mass of 1 mol of cobalt(II) chloride hexahydrate is 237 g. 100 mL of a solution (1 mol/L) contains 23.7 g of cobalt(II) chloride hexahydrate.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 4 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 5) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you will be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.....25)

| DESIGN (5 marks) | | CLUES (9 marks) | PERFORMANCE (11 marks) | |
|---|---|---|---|---|
| NONE | 0 | No. 1 ___(2) | Solution A | |
| FAULTY (requires an initial clue) | 2 | No. 2 ___(2) | Experimental Error | |
| | | | >50% ___ | 0 |
| | | No. 3 ___(2) | 35-50% ___ | 2 |
| FAULTY (does not require an initial clue) | 3 | | 20-35% ___ | 4 |
| | | No. 4 ___(2) | <20% ___ | 6 |
| GOOD AND WORKABLE | 5 | No. 5 ___(9) | Solution B | |
| | | | Experimental Error | |
| | | | >40% ___ | 0 |
| | | | 20-30% ___ | 3 |
| | | | <20% ___ | 5 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.
(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. CLUES

### Clue No. 1

Prepare 100 mL of a 1.0 mol/L solution of cobalt(II) chloride and examine the colour intensity of this solution.

### Clue No. 2

Use the cobalt(II) chloride hexahydrate (1.0 mol/L) solution to prepare several more dilute solutions of cobalt(II) chloride of known concentration.

### Clue No. 3

Intensity of colour is a measure of concentration. Examine the colours of the cobalt chloride solutions by holding them over the light source.

### Clue No. 4

$$\text{Concentration}_{\text{UNKNOWN}} = \frac{\text{Depth}_{\text{STANDARD}}}{\text{Depth}_{\text{UNKNOWN}}} \times \text{Concentration}_{\text{STANDARD}}$$

### Procedural Clue (Clue No. 5)

1. Dissolve 23.7 g of cobalt(II) chloride hexahydrate in sufficient water to make 100 mL of solution.

2. Prepare a series of cobalt(II) chloride solutions by dilution with water.

   a) 50 mL of standard solution (1.0 mol/L) to 100 mL.
   b) 25 mL of standard solution (1.0 mol/L) to 100 mL.
   c) 10 mL of standard solution (1.0 mol/L) to 100 mL.
   d) 5 mL of standard solution (1.0 mol/L) to 100 mL.

3. Observe the colour intensities of the solutions by viewing them through the vertical depth of liquid.

4. Match the colour viewed through the unknown solution(s) with one of the known solutions.

5. Calculate the concentration of the unknown solution(s).

$$\text{Concentration}_{\text{UNKNOWN}} = \frac{\text{Depth}_{\text{STANDARD}}}{\text{Depth}_{\text{UNKNOWN}}} \times \text{Concentration}_{\text{STANDARD}}$$

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) An overhead projector can be used as a light box. Place a sheet of paper over the stage of the projector in order to produce a source of diffuse white light.

(b) Substitute a variety of coloured salts for cobalt chloride.

(c) The concentrations of the unknowns should be accepted within wide limits (20%).

(d) This problem is a variation on the $KSCN/Fe(NO_3)_3$ equilibrium experiment.

**CLUE Model**
**PROBLEM NO. 25**

## Scoring Guide

Student ____________________

Date ____________________

Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5 ______________________
6. ______________________
7. ______________________
8. ______________________
9 ______________________
______________________

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## For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution. ☐ 5

**Experimental Design (5 marks)**

(Please check the appropriate level and enter mark in Space I)

| | | |
|---|---|---|
| None | ______ | 0 |
| Faulty (requires an initial CLUE) | ______ | 2 |
| Faulty (does not require an initial CLUE) | ______ | 3 |
| Good and Workable | ______ | 5 |

**Clues (9 marks)**

(Please check the **CLUES** that were given to the student. Enter the net marks obtained by the student for **CLUES** in Space II)

Net Mark = 9 - (CLUES used)

| | |
|---|---|
| CLUE No. 1 | 2 |
| CLUE No. 2 | 2 |
| CLUE No. 3 | 2 |
| CLUE No. 4 | 2 |
| Procedural CLUE | 9 |

**Performance (11 marks)**

(Please enter the appropriate mark in Space III)

Solution A

| Experimental Error | | |
|---|---|---|
| >50% | ______ | 0 |
| 35-50% | ______ | 2 |
| 20-35% | ______ | 4 |
| <20% | ______ | 6 |

Solution B

| Experimental Error | | |
|---|---|---|
| >40% | ______ | 0 |
| 20-30% | ______ | 3 |
| <20% | ______ | 5 |

| Experimental Design | Clues | Performance |
|---|---|---|
| ○ I | ○ II | ○ III |

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# CLUE Model PROBLEM NO. 26

## I. INTRODUCTION

So far in your study of chemistry you have looked at and worked with many different substances. You must have observed that many substances dissolve in water and that some of these soluble substances produce coloured solutions. In this problem you will investigate coloured solutions.

## II. SPECIAL LAB KIT

beakers
eye droppers
light sources
pipets
flasks
cobalt(II) chloride hexahydrate
test tubes (uniform size)
balances (centigram)
2 unknown solutions (labelled A and B)
graduated cylinders

DATA:

(a) The solubility of cobalt(II) chloride is approximately 50 g per 100 g of water at room temperature.
(b) The solution is coloured.
(c) The mass of 1 mol of cobalt(II) chloride hexahydrate is 237 g. 100 mL of a solution (1 mol/L) contains 23.7 g of cobalt(II) chloride hexahydrate.

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to:

(a) determine if there is any relationship between the concentration of a solution and the amount (or intensity) of the colour that the solution exhibits,
(b) determine the nature of the relationship if one exists, and
(c) determine the concentration of two solutions of cobalt chloride of unknown concentration.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 4 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 5) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you will be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.....25)

| DESIGN (5 marks) | |
|---|---|
| NONE | 0 |
| FAULTY (requires an initial clue) | 2 |
| FAULTY (does not require an initial clue) | 3 |
| GOOD AND WORKABLE | 5 |

| CLUES (9 marks) | |
|---|---|
| No. 1 | ____(2) |
| No. 2 | ____(2) |
| No. 3 | ____(2) |
| No. 4 | ____(2) |
| No. 5 | ____(9) |

| PERFORMANCE (11 marks) | | |
|---|---|---|
| a) Is there a relationship | ____ | 1 |
| b) Nature of relationship? | ____ | 3 |
| c) Solution A Experimental Error | | |
| >50% | ____ | 0 |
| 35-50% | ____ | 2 |
| 20-35% | ____ | 3 |
| <20% | ____ | 4 |
| d) Solution B Experimental Error | | |
| >40% | ____ | 0 |
| 20-40% | ____ | 1 |
| <20% | ____ | 3 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. CLUES

### Clue No. 1

Prepare 100 mL of a solution of cobalt(II) chloride hexahydrate (1.0 mol/L) and examine the colour intensity of this solution.

### Clue No. 2

Use the cobalt(II) chloride solution (1.0 mol/L) to prepare several more dilute solutions of cobalt chloride of known concentration.

### Clue No. 3

Examine the colours of the cobalt chloride solutions by holding them over the light source.

### Clue No. 4

Compare the colour of the unknown solution to the colour of the solutions which you prepared.

### Procedural Clue (Clue No. 5)

1. Dissolve 23.7 g of cobalt(II) chloride hexahydrate in sufficient water to make 100 mL of solution.

2. Prepare a series of cobalt(II) chloride solutions by dilution with water.

   a) 50 mL of standard solution (1.0 mol/L) to 100 mL.
   b) 25 mL of standard solution (1.0 mol/L) to 100 mL.
   c) 10 mL of standard solution (1.0 mol/L) to 100 mL.
   d) 5 mL of standard solution (1.0 mol/L) to 100 mL.

3. Match the colour of unknown A with one of the dilutions.

4. Calculate the concentration of Unknown A.

$$\text{Concentration}_{\text{UNKNOWN}} = \frac{\text{Depth}_{\text{STANDARD}}}{\text{Depth}_{\text{UNKNOWN}}} \times \text{Concentration}_{\text{STANDARD}}$$

5. Repeat with unknown B.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) An overhead projector can be used as a light box. Place a sheet of paper over the stage of the projector in order to produce a source of diffuse white light.

(b) Substitute a variety of coloured salts for cobalt chloride.

(c) The concentrations of the unknowns should be accepted within wide limits (20%).

(d) This problem is a variation on the $KSCN/Fe(NO_3)_3$ equilibrium experiment.

**CLUE Model PROBLEM NO. 26**

**Scoring Guide**

Student ____________________

Date ____________________

Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

# CLUE Model PROBLEM NO. 27

## I. INTRODUCTION

The labels (A,B,C and D) have come off a set of solid organic acids. The identity of the acids is necessary in order for the materials to be used in the laboratory.

## II. SPECIAL LAB KIT

buret
pipet
pipet bulb
sodium hydroxide solution (0.2 mol/L)
hydrochloric acid solution (0.2 mol/L)
phenolphthalein solution
bromothymol blue solution
litmus paper
set of organic acids (A,B,C and D)

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to identify the set of organic acids (A,B,C and D). In alphabetical order, the acids are ______________,

______________, ______________ and ______________.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 6 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 7) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you will be given a CLUE if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.....25)

| DESIGN (5 marks) | | CLUES (9 marks) | PERFORMANCE (11 marks) | |
|---|---|---|---|---|
| NONE | 0 | No. 1 ___(2) | | |
| FAULTY (requires an initial clue) | 2 | No. 2 ___(2) | 4 labels correct ____ | 11 |
| | | No. 3 ___(1) | 3 labels correct ____ | 7 |
| FAULTY (does not require an initial clue) | 3 | No. 4 ___(1) | 2 labels correct ____ | 5 |
| GOOD AND WORKABLE | 5 | No. 5 ___(1) | 1 label correct ____ | 0 |
| | | No. 6 ___(1) | | |
| | | No. 7 ___(9) | | |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. CLUES

Clue No. 1
Acids can be identified by a characteristic property such as molar mass.

Clue No. 2
Molar mass of an acid can be determined by titration with a base of known concentration.

Clue No. 3
Use a piece of "weighing" paper; weigh 1 g of acid A.

Clue No. 4
Each of the acids is monobasic.
No. of moles of acid = No. of moles of base

Clue No. 5

$$\text{No. of moles of acid} = \frac{\text{mass of acid}}{\text{molar mass}}$$

$$\text{No. of moles of base} = V_{(L)} \times \text{Concentration (mol/L)}$$

Clue No. 6
Molar masses of the acids (A,B,C and D) are:

________________ _____g ________________ _____g

________________ _____g ________________ _____g

Procedural Clue (Clue No. 7)

1. Find the mass of a sheet of "weighing paper".
2. Add a quantity of Acid A to the paper (about 1 g) and determine the mass of the paper and the sample of Acid A.
3. Add the sample of Acid A to 25 mL of distilled water in an Erlenmeyer flask.
4. Shake to dissolve the acid.
5. Add 3 drops of phenolphthalein solution to the acid solution.
6. Fill a buret with sodium hydroxide solution (0.2 mol/L).
7. Add sodium hydroxide solution until the solution just turns pink.
8. Record the volume of sodium hydroxide solution required.
9. Calculate the number of moles of sodium hydroxide consumed.
10. No. of moles of acid = No. of moles of sodium hydroxide.
11. Calculate the mass of one mole of acid A.
12. Repeat with acids B,C and D.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Select acids that are all monobasic (monoprotic).

(b) Select acids that are soluble in water.

(c) Select acids that differ in molar mass by at least 10%.

(d) In the PROBLEM section (III) list the compounds both by name and by formula.

(e) Clue No. 6 - List the compounds both by name and by formula.

(f) Some sample acids are:

benzoic acid
citric acid
oleic acid
stearic acid
potassium hydrogen carbonate
potassium hydrogen phthalate
potassium hydrogen tartrate
lauric acid

**CLUE Model PROBLEM NO. 27**

**Scoring Guide**

Student ____________________

Date ____________________

Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

# CLUE Model PROBLEM NO. 28

## I. INTRODUCTION

The chemist is frequently called upon to identify an unknown metal. On some of these occasions the materials and equipment available for use are limited. All of the initial observations indicate that the unknown metal is divalent.

## II. SPECIAL LAB KIT

100 mL graduated cylinder
hydrochloric acid (2 mol/L)
gelatin capsule containing powdered metal
thermometer
sodium hydroxide solution (0.5 mol/L)
pipet
buret
phenolphthaolein solution
bromothymol blue solution
A barometer will be available in the laboratory.

## III. PROBLEM

You are provided with a capsule containing a sample of a powdered metal. The metal is one of a)______________,

b)______________ , c)______________ , d)______________.

Using only the materials in the "SPECIAL LAB KIT" design an experiment to determine the identity of the metal.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do Not proceed with the actual experimental work until the teacher has checked and approved the experimental design that you have suggested.

NOTE - You are also provided with a kit of standard laboratory glassware and hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the "laboratory design" 15 min

## VI. TEST FORMAT

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are 5 CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No. 6) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 min you will be given a clue if the Design you presented is not sufficient to allow you to start performing laboratory work.

## VII. EVALUATION SCHEME (Total possible score.....25)

| DESIGN (5 marks) | |
|---|---|
| NONE | 0 |
| FAULTY (requires an initial clue) | 2 |
| FAULTY (does not require an initial clue) | 3 |
| GOOD AND WORKABLE | 5 |

| CLUES (9 marks) | | |
|---|---|---|
| No. 1 | ___ | 2 |
| No. 2 | ___ | 2 |
| No. 3 | ___ | 1 |
| No. 4 | ___ | 2 |
| No. 5 | ___ | 1 |
| No. 6 | ___ | 9 |

PERFORMANCE (11 marks)

1. Marks are awarded on the basis of the % error in the experimental data.

| Experimental Error | |
|---|---|
| > 30% | 0 |
| 20 - 30% | 1 |
| 10 - 20% | 2 |
| 0 - 10% | 3 |

2. Calculations 5

| | |
|---|---|
| a) Step 1 | 2 |
| b) Step 2 | 1 |
| c) Step 3 | 2 |

3. Identification of the metal. 3

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. CLUES

### Clue No. 1

Most metals react readily with hydrochloric acid.

$$M(s) + 2H^{+}(aq) \rightarrow M^{2+}(aq) + H_2(g)$$

### Clue No. 2

The quantity of hydrochloric acid remaining can be determined by titration.

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O$$

### Clue No. 3

The quantity of hydrochloric acid consumed can be calculated from the titration data.

### Clue No. 4

$$\text{No. of moles of metal} = \frac{\text{No. of mol of HCl consumed}}{2}$$

### Clue No. 5

$$\frac{\text{Mass of Metal}}{\text{No. of moles of mole}} = \text{Relative Atomic Mass}$$

Procedural Clue (Clue No. 6)

(1) Use the graduated cylinder to measure 100 mL of the hydrochloric acid (HCl) solution.

(2) Pour the HCl into a 600 mL beaker.

(3) Determine the mass of the capsule and the metal.

(4) Empty the contents of the capsule into the HCl solution.

(5) Determine the mass of the empty capsule.

(6) Calculate the mass of metal used.

(7) Allow the reaction to proceed to completion.

(8) Add three drops of bromothymol blue solution to the reaction vessel.

(9) Fill a buret with the sodium hydroxide solution.

(10) Titrate the excess acid with the sodium hydroxide solution until the colour of the system indicates that the system is neutral.

(11) Record the volume of sodium hydroxide solution.

(12) $M(s) + 2HCl(aq) \rightarrow MCl_2(aq) + H_2(g)$

(13) $M(s) + 2H^+(aq) \rightarrow M^{2+}(aq) + H_2(g)$

(14) Volume of sodium hydroxide, NaOH, consumed = ______ mL

(15) No. of moles of NaOH consumed = vol(L) x Concentration (mol/L)
= y mol

(16) No. of moles of HCl in 100 mL of solution $= \frac{100}{1000} \times 2.0$
$= 0.20$ mol

(17) No. of moles of HCl consumed = (0.20 - y) mol

(18) No. of moles of metal in the sample $= \frac{0.20 - y}{2}$ mol

(19) Relative Atomic Mass of the metal

$$= \frac{\text{Mass of Metal}}{\text{No. of mol of metal}}$$

(20) The metal can now be identified by comparing the calculated Relative Atomic Mass of the metal with the published values for the metals listed in the Problem section (III).

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a) React the metal with acid and evaporate to dryness.
(b) React the metal with acid and collect the hydrogen gas.
(c) React the metal with oxygen and determine the mass of the oxide.
(d) React the metal with oxygen and determine the mass of the chloride.
(e) React the metal with steam and determine the mass of the oxide.

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(1) The metals that may be used are:

| | | | | | |
|---|---|---|---|---|---|
| Magnesium | (Mg) | 24.2 | Nickel | (Ni) | 58.7 |
| Calcium | (Ca) | 40.1 | Zinc | (Zn) | 65.4 |
| Chromium | (Cr) | 52.0 | Cadmium | (Cd) | 112.4 |
| Iron | (Fe) | 55.9 | Tin | (Sn) | 118.7 |

$$M(s) + 2H^{+}(aq) \rightarrow M^{2+}(aq) + H_2(g)$$

(2) Provide the students with sufficient metal to consume about 75% of the acid.
(3) Provide the students with "correct" concentrations of the hydrochloric acid and sodium hydroxide solutions.
(4) In section III indicate to the student four (4) of the metals listed (one of them to be the correct answer).
(5) Select four metals with significantly different atomic weights so that the student can readily get the correct answer.
e.g. (a) Mg, Ca, Cd, Zn (b) Ca, Mg, Fe, Sn (c) Zn, Cr, Sn, Mg
(6) Check that the metal(s) you have selected do react completely with the acid. You may have to increase the acid concentration.
(7) Provide a variety of sizes of beakers and graduated cylinders for the students to select.

## CLUE Model PROBLEM NO. 28

### Scoring Guide

Student ____________________

Date ____________________

Score ____________________

### A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

### B. Observations

Clue
Model

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________
7. ____________________
8. ____________________
9. ____________________

____________________

---

## For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

**xperimental Design 5 marks)**

Please check the appropriate evel and enter mark in Space I)

| | |
|---|---|
| None | ____ 0 |
| Faulty (requires an initial CLUE) | ____ 2 |
| Faulty (does not require an initial CLUE) | ____ 3 |
| Good and Workable | ____ 5 |

**Clues (9 marks)**

(Please check the **CLUES** that were given to the student. Enter the net marks obtained by the student for **CLUES** in Space II)

Net Mark = 9 - (CLUES used)

| | |
|---|---|
| CLUE No. 1 | 2 |
| CLUE No. 2 | 2 |
| CLUE No. 3 | 1 |
| CLUE No. 4 | 2 |
| CLUE No. 5 | 1 |
| Procedural CLUE | 9 |

**Performance (11 marks)**

(Please enter the appropriate mark in Space III)

Marks are awarded on the basis of the % error in the experimental data.

| Fxperimental Error | |
|---|---|
| > 30% | 0 |
| 20 - 30% | 1 |
| 10 - 20% | 2 |
| 0 - 10% | 3 |
| Calculations | 5 |
| a) Step 1 | 2 |
| b) Step 2 | 1 |
| c) Step 3 | 2 |
| Identification of the metal | 3 |

**Experimental Design** ○ I

**Clues** ○ II

**Performance** ○ III

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

## Procedural Step Model
## PROBLEM NO. 1

## I. INTRODUCTION

The chemist is frequently called upon to identify a series of "unknown" materials. On some of these occasions the materials and equipment available for use are limited.

## II. SPECIAL LAB KIT

Vials labelled respectively A, B, C, D and E.
Litmus paper (red and blue)
Light bulb assembly
Silver nitrate solution, $AgNO_3$, ($10^{-3}$mol/L) in a dropper bottle
Hydrochloric acid, HCl, (1 mol/L) in a dropper bottle

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to correctly identify the contents of the five vials labelled A, B, C, D and E. Predict the observations that you would expect. Indicate how you would use these observations to identify the unknowns. The labels from five laboratory containers came off the containers and were mixed up. The labels, listed in alphabetical order are barium hydroxide, calcium carbonate, citric acid, sodium chloride and sugar. Individual samples of the five materials are contained in the vials labelled A, B, C, D and E.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated. You will be given a complete procedure to follow unless you have presented a procedure which has been evaluated as complete and workable.

## VII. EVALUATION SCHEME (Total possible score.......25)

| DESIGN (15 marks) | | | PERFORMANCE (10 marks) | |
|---|---|---|---|---|
| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) | | |
| 1. ____ | 1. ____ | 1. ____ | 0 labels correct | 0 |
| 2. ____ | 2. ____ | 2. ____ | 1 label correct | 2 |
| 3. ____ | 3. ____ | 3. ____ | 2 labels correct | 4 |
| 4. ____ | 4. ____ | 4. ____ | 3 labels correct | 6 |
| 5. ____ | 5. ____ | 5. ____ | 5 labels correct | 10 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

Add a small sample of each solid to distilled water in individual test tubes.

### PROCEDURAL STEP No. 2

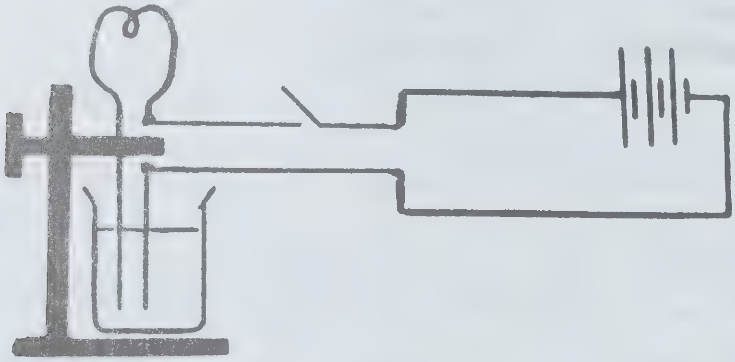
Determine the qualitative solubility (insolubility) of the solids in water. Only one of the solids is insoluble in water.

### PROCEDURAL STEP No. 3

Test the solutions with litmus paper. Red litmus turns blue in basic solution; blue litmus turns red in acidic solution.

### PROCEDURAL STEP No. 4

Use the light bulb assembly to distinguish between electrolytes and non-electrolytes. When the electrodes are immersed in an electrolyte the bulb will glow.



### PROCEDURAL STEP No. 5

Add a few drops of silver nitrate solution to the two remaining unknowns. A precipitate will form in one of the solutions.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The teacher is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The teacher has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions

(a) To a small sample of each solid add the same volume of water. All of the solids will dissolve except calcium carbonate. The student may verify the identity of the calcium carbonate by the addition of hydrochloric acid.

It is not necessary that a confirmatory test be performed.

(b) Test the four solutions with litmus paper. The litmus paper will turn red in the citric acid, turn blue in the barium hydroxide solution and remain unchanged in the sodium chloride solution.

(c) Test the sodium chloride and sugar solutions for electrical conductivity. The conductivity will be greater in the sodium chloride solution.

The bulb will light in the sodium chloride solution if the concentration of the solutin is at least 0.02 mol/L. If the concentration is less than 0.02 mol/L it may be possible to observe signs of electrolysis (gas formation).

or

(d) Silver nitrate solution will produce a white precipitate with sodium chloride solution, but not with sugar solution.

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Change the coding scheme for those candidates who are NOT in the laboratory at the same time. Students in the laboratory at the same time can have the same coding.

(b) The conductivity apparatus can be made with almost any metals. The bulb will "light" in very dilute (0.02 mol/L) electrolytes.

(c) The electrodes should NOT be shorted out. The bulb (1.5 volts or less) will "blow" easily. Have spare bulbs available.

(d) The dry cell is a nine (9) volt cell.

## Procedural Step Model
PROBLEM NO. 1

**Scoring Guide**

Student ____________________

Date ____________________

Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

# Procedural Step Model
# PROBLEM NO. 2

## I. INTRODUCTION

It is frequently necessary to remove an ion from a given solution This procedure can be performed in a variety of ways. The technique depends on the initial solution and the materials provided.

## II. SPECIAL LAB KIT

Dropper bottles containing 0.1 mol/l solutions of:

potassium chromate $K_2CrO_4$
nitric acid $HNO_3$
3 medicine droppers
10 mL graduated cylinder
ammonium nitrate $NH_4NO_3$
lead(II) nitrate $Pb(NO_3)_2$
Gummed labels
Spot plates (black and white)
Stoppered test tube labelled "for testing by the teacher"

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to

1) remove all the chromate ion, $CrO_4^{2-}(aq)$, from 10 mL of potassium chromate, $K_2CrO_4(aq)$, (0.1 mol/L) without introducing any excess of the species used to carry out the appropriate removal procedure.
2) verify that you have carried out the removal of chromate ion ($CrO_4^{2-}(aq)$,completely, and also that there is no excess of the removing agent.
3) provide at least 6 mL of the resultant solution for the teacher to test.
4) As a preliminary step to developing your detailed design indicate to your teacher the reagent you will use to remove the chromate ion.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated. You will be given a complete procedure to follow unless you have presented a procedure which has been evaluated as complete and workable.

## VII. EVALUATION SCHEME (Total possible score.......25)

DESIGN (15 marks)

| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) |
|---|---|---|
| 1. ____ | 1. ____ | 1. ____ |
| 2. ____ | 2. ____ | 2. ____ |
| 3. ____ | 3. ____ | 3. ____ |
| 4. ____ | 4. ____ | 4. ____ |
| 5. ____ | 5. ____ | 5. ____ |

PERFORMANCE (10 marks)

| | |
|---|---|
| 1. Selected correct solution | 1 |
| 2. Calculated correct amount of solution | 2 |
| 3. Provided at least 6 mL of solution | 3 |
| 4. No excess of either ion in solution | 4 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

1. Pour potassium chromate solution to a depth of 1 cm into each of three test tubes.

2. Add a few drops of the nitric acid solution, the lead(II) nitrate solution and the ammonium nitrate solution to each of the samples of the potassium chromate solution.

### PROCEDURAL STEP No. 2

1. Select the solution which may be used to remove the chromate ion by observing which of the added solutions caused a precipitate to form.

2. The equation for the reaction of chromate ion and the "removing ion" must be written and balanced.

### PROCEDURAL STEP No. 3

The number of moles of chromate ion, $CrO_4^{2-}$ in 10 mL of the $K_2CrO_4$ solution is $\frac{10}{1000} \times 0.1 = 0.001$ mol.

### PROCEDURAL STEP No. 4

1. Since the precipitate is lead(II) chromate, $PbCrO_4$, the volume of lead(II) nitrate, $Pb(NO_3)_2$, solution can now be calculated.

2. Add the appropriate volume of lead(II) nitrate, $Pb(NO_3)_2$, solution to the 10 mL of the potassium chromate, $K_2CrO_4$, solution.

3. Filter the mixture.

### PROCEDURAL STEP No. 5

1. Test samples of the filtrate with each of potassium chromate and lead(II) nitrate solutions. If a precipitate forms in either case then one of the ions is still present.

2. Pour the remaining filtrate into the labelled test tube for examination by the teacher.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The teacher is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The teacher has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Allow the students to perform the preliminary experimental work to identify the removing agent before they write their Design.

(b) The teacher's testing of the filtrates must allow for a measure of error. Test 2 mL of the filtrate with one drop of each of the test solutions.

(c) Change the identity of the "removing solutions" for different classes.

(d) Change the identity (concentration) of the known (potassium chromate) solution for different students and/or classes.

(e) Change the concentration of the "removing solution" for different students and/or classes.

NOTE If any of these changes are made then the PROCEDURAL STEPS and the content of the problem may have to be changed slightly.

**Procedural Step Model**
**PROBLEM NO. 2**

**Scoring Guide** PSM.2(5)

Student ____________________
Date ____________________
Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

# Procedural Step Model
# PROBLEM NO. 3

## I. INTRODUCTION

The chemist is frequently called upon to identify an unknown metal. On some of these occasions the materials and equipment available for use are limited. All of the initial observations indicate that the unknown metal is divalent.

## II. SPECIAL LAB KIT

bottle of hydrochloric acid solution, 6 mol/L
gelatin capsule containing powdered metal of known mass
thermometer
A barometer will be available in the laboratory.
100 mL graduated cylinder

capsule, ____ g.

## III. PROBLEM

You are provided with a capsule containing a known mass of a powdered metal. The metal is one of a) ________________,

b) ____________, c) ____________, d) ________________.

Using only the materials in the "SPECIAL LAB KIT" design an experiment to determine the identity of the metal. You will be given the mass of the metal in the gelatin capsule.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

### V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

### VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated. You will be given a complete procedure to follow unless you have presented a procedure which has been evaluated as complete and workable.

### VII. EVALUATION SCHEME (Total possible score.......25)

DESIGN (15 marks)

| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) |
|---|---|---|
| 1. ____ | 1. ____ | 1. ____ |
| 2. ____ | 2. ____ | 2. ____ |
| 3. ____ | 3. ____ | 3. ____ |
| 4. ____ | 4. ____ | 4. ____ |
| 5. ____ | 5. ____ | 5. ____ |

PERFORMANCE (10 marks)

1. Experimental Error
   - >30%____0
   - 20-30%____1
   - 10-20%____2
   - <10%____3
2. Calculations
   - a) Step 1____2
   - b) Step 2____1
   - c) Step 3____2
3. Identification of the metal.___2

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

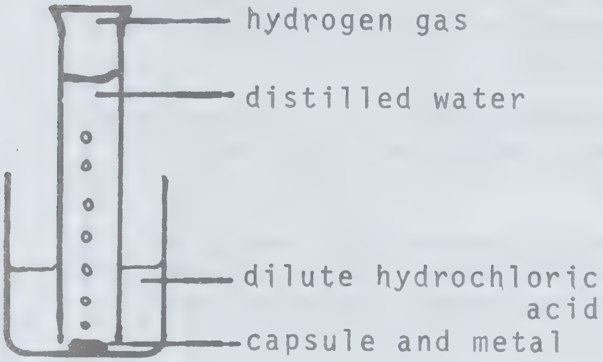
(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

1. Completely fill a graduated cylinder with distilled water and invert it over the capsule in a beaker containing 100 mL of distilled water.
2. Add 50 mL of 6 mol/L hydrochloric acid, HCl, to the water in the beaker.



1. Invert the cylinder into water only; do not add acid to the water yet.
2. Be sure to cover the capsule with the full graduated cylinder.
3. Add the acid after the cylinder is inverted in the beaker of water.

### PROCEDURAL STEP No. 2

Allow the reaction to proceed until all the metal is consumed.

### PROCEDURAL STEP No. 3

Measure the volume of hydrogen gas produced in the reaction.

### PROCEDURAL STEP No. 4

Calculate the atomic mass of the metal using the number of moles of gas collected to calculate the number of moles of metal consumed.

### PROCEDURAL STEP No. 5

$$\text{Atomic mass} = \frac{\text{Mass of metal in the capsule}}{\text{No. of mol of metal consumed}}$$

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The examiner is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The examiner has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) The metals that may be used are:

| | | | | |
|---|---|---|---|---|
| All of the metals are divalent. | Magnesium | (Mg - 24.2) | Nickel | (Ni - 58.7) |
| | Calcium | (Ca - 40.1) | Zinc | (Zn - 65.4) |
| | Chromium | (Cr - 52.0) | Cadmium | (Cd - 112.4) |
| | Iron | (Fe - 55.9) | Tin | (Sn - 118.7) |

$$M(s) + 2H^{+}(aq) \rightarrow M^{2+}(aq) + H_2(g)$$

(b) The metals and their masses have been chosen so that the corrections for STP and vapour pressure are unnecessary. The errors generated will be small.

(c) The mass of metal in the capsule should be selected so that approximately 100 mL of $H_2$ gas will be produced.

(d) In section III indicate to the students four (4) of the metals listed (one of them must be the correct answer).

(e) Select the four metals with significantly different atomic weights so that the student can readily get the correct

(f) Use this problem as an example for discussion purposes.

(g) Soluble gelatin capsules are difficult to obtain.

**Procedural Step Model**
**PROBLEM NO. 3**

**Scoring Guide**

Student ____________________

Date ____________________

Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________________ 6. ______________________
2. ______________________ 7 ______________________
3. ______________________ 8 ______________________
4. ______________________ 9 ______________________
5. ______________________ ______________________

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## For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

**Experimental Design (15 marks)**

(Please indicate with a check mark the **procedural steps** designed correctly and the **procedural steps** given to the student)

| Steps Designed Correctly | | Steps Given to the Student |
|---|---|---|
| **Phase I** | **Phase II** | |
| 1. ______ | 1. ______ | 1. ______ |
| 2. ______ | 2 ______ | 2. ______ |
| 3. ______ | 3. ______ | 3 ______ |
| 4. ______ | 4. ______ | 4. ______ |
| 5. ______ | 5. ______ | 5. ______ |

**Performance (10 marks)**

(Please enter the appropriate mark in Space III)

Experimental Error
>30% ______ 0
20-30% ______ 1
10-20% ______ 2
<10% ______ 3

Calculations
a) Step 1 ______ 2
b) Step 2 ______ 1
c) Step 3 ______ 2

Identification of the metal. ______ 2

**Experimental Design**

**Phase I**
**No. of steps x 3**
○ I

**Phase II**
**No. of steps x 2**
○ II

**Performance**
○ III

---

Total Score ○ I + ○ II + ○ III = ⬡ TOTAL

# Procedural Step Model
# PROBLEM NO. 4

## I. INTRODUCTION

A common problem faced by chemists is to determine the concentration of an acid solution. There are various techniques for doing this.

## II. SPECIAL LAB KIT

Hydrochloric acid solution, HCl (0.1 mol/L), 250 mL
Sodium hydroxide solution, NaOH (0.1 mol/L), 250 mL
4 acid solutions (A, B, C, D) of unknown concentration in the range of 0.0001 mol/L to 0.20 mol/L .
Stop watch (watch or clock with "sweep" second hand)
Magnesium ribbon (1 Metre)
Bromothymol blue solution
pH paper
crayon pencil

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment arrange the 4 unknown acids A, B, C and D in decreasing order of concentration. The range in concentrations of the unknowns is from 0.0001 mol/L to 0.20 mol/L .

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated. You will be given a complete procedure to follow unless you have presented a procedure which has been evaluated as complete and workable.

## VII. EVALUATION SCHEME (Total possible score.......25)

| DESIGN (15 marks) | | | PERFORMANCE (10 marks) | |
|---|---|---|---|---|
| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) | | |
| 1. ____ | 1. ____ | 1. ____ | 4 correct | 10 |
| 2. ____ | 2. ____ | 2. ____ | 3 correct | 7 |
| 3. ____ | 3. ____ | 3. ____ | 2 correct | 4 |
| 4. ____ | 4. ____ | 4. ____ | 1 correct | 1 |
| 5. ____ | 5. ____ | 5. ____ | 0 correct | 0 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. PROCEDURAL STEPS

Three possible methods are provided in the procedural steps, (a), (b), and (c). When providing steps, the teacher should consistently use either part (a), (b) or )c) from each step, depending on the students' needs.

### PROCEDURAL STEP No. 1

(a) Prepare 10 mL of 0.01 mol/L hydrochloric acid.
  (i) Measure 1 mL of 0.1 mol/L hydrochloric acid in a 10 mL graduated cylinder.
  (ii) Add water to make 10 mL of solution.

or

(b) Prepare four (4) strips of magnesium ribbon, each approximately 4 cm in length.

or

(c) Pour 5 mL of solutions A, B, C and D into separate test tubes.

### PROCEDURAL STEP No. 2

(a) Prepare 10 mL of 0.001 mol/L hydrochloric acid.
  (i) Measure 1 mL of 0.01 mol/L hydrochloric acid in a 10 mL graduated cylinder.
  (ii) Add water to make 10 mL of solution.

or

(b) Pour solutions A, B, C and D into separate test tubes, each to a depth of approximately 4 cm.

or

(c) Label the test tubes A, B, C and D.

### PROCEDURAL STEP No. 3

(a) Prepare 10 mL of 0.0001 mol/L hydrochloric acid.
  (i) Measure 1 mL of 0.001 mol/L hydrochloric acid in a 10 mL graduated cylinder.
  (ii) Add water to make 10 mL of solution.

or

(b) Label the test tubes A, B, C and D.

or

(c) Add 3 drops of bromothymol blue solution to each of the four test tubes.

### PROCEDURAL STEP No. 4

(a) Test the 0.1, 0.01, 0.001, and 0.0001 mol/L hydrochloric acid solutions with pH paper. Test solutions A, B, C and D with pH paper.

or

(b) Put the magnesium strips into each of the test tubes.

or

(c) Add 0.1 mol/L sodium hydroxide, dropwise to each test tube until the bromothymol blue changes colour.

### PROCEDURAL STEP No. 5

(a) Arrange the unknown solutions (A, B, C and D) in order of decreasing concentration as indicated by the pH paper.

or

(b) Arrange the test tubes according to rate of reaction.

or

(c) Count the number of drops added to each test tube. Arrange the solutions in order of decreasing concentration.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines three of the many possible procedures that might be designed by the students.

The teacher is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The teacher has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions
The student has a choice of at least three (3) procedures that can be followed using the materials in the lab kit.

### (a) Use of pH paper

(i) Prepare a series of diluted standards by diluting the 0.1 mol/L HCl (given) with distilled water.
(ii) Test the pH - or - compare the colours of the pH paper in each of the diluted samples.
(iii) Test the pH - or - compare the colours of the pH paper in each of the unknowns.
(iv) Arrange the unknowns in the same colour order as the diluted standards.

### (b) Rate or Reaction

(i) Prepare four strips of Mg ribbon of the same length.
(ii) Allow the lengths of Mg ribbon to react with equal volumes of each of the "unknown" acids.
(iii) Compare the rate of production of gas bubbles on the four strips of magnesium ribbon.
(iv) The more concentrated the acid the faster the bubbles are produced.

### (c) Titration

(i) Place equal volumes of each of the unknown acids in each of four test tubes.
(ii) Add a few drops of bromothymol blue indicator solution to each sample of acid. The solutions will turn yellow.
(iii) Add 0.1 mol/L sodium hydroxide (NaOH), solution dropwise to each of the acids until the solution turns green or blue; count the number of drops of NaOH solution required.
(iv) The more concentrated acid solutions will require larger volumes of sodium hydroxide solution for complete neutralization.

## X. SPECIFIC LABORATORY AND SECURITY ARRANGEMENTS

1. The individual teacher may choose to omit one or more procedures simply by omitting materials from the SPECIAL LAB KIT.

2. Students in the laboratory at the same time may have the same coding (A, B, C and D). The coding must be changed for succeeding groups of students.

3. Provide sufficient test tubes, and distilled water so that students can rinse equipment easily.

4. The acid solutions need not be prepared and standardized carefully. It is sufficient for the teacher to know the decreasing order of concentrations.

5. The teacher may choose to use acid solutions more concentrated than 0.1 mol/L.

6. The teacher must decide how to supply the PROCEDURAL STEPS. It may be better to give students only one of the sections of the PROCEDURAL STEPS. The section(s) given to the students will be determined by the progress (or lack of progress) made by the students.

# Procedural Step Model

# PROBLEM NO. 4

**Scoring Guide**

Student ______________________

Date ______________________

Score ______________________

## Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

| | | | |
|---|---|---|---|
| 1. ____________ | | 6. ____________ | |
| 2. ____________ | | 7. ____________ | |
| 3. ____________ | | 8. ____________ | |
| 4. ____________ | | 9. ____________ | |
| 5 ____________ | | ____________ | |

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## For Teacher's Use Only

### Alternate Solution(s)

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

### Experimental Design (15 marks)

(Please indicate with a check mark the **procedural** steps designed correctly and the **procedural steps** given to the student)

| Steps Designed Correctly | | Steps Given to the Student |
|---|---|---|
| **Phase I** | **Phase II** | |
| 1 ______ | 1. ______ | 1 ______ |
| 2. ______ | 2. ______ | 2. ______ |
| 3. ______ | 3. ______ | 3. ______ |
| 4 ______ | 4. ______ | 4. ______ |
| 5 ______ | 5 ______ | 5. ______ |

### Performance (10 marks)

(Please enter the appropriate mark in Space III)

| | |
|---|---|
| 4 correct | 10 |
| 3 correct | 7 |
| 2 correct | 4 |
| 1 correct | 1 |
| 0 correct | 0 |

### Experimental Design

| Phase I<br>No. of steps x 3 | Phase II<br>No. of steps x 2 | Performance |
|---|---|---|
| ○ I | ○ II | ○ III |

Total Score ○ I + ○ II + ○ III = ⬡ TOTAL

# Procedural Step Model PROBLEM NO. 5

## I. INTRODUCTION

Many chemical compounds are coloured due to the presence of certain ions or a combination of ions. In this problem you will be asked to determine which ions or combination of ions form a coloured product.

## II. SPECIAL LAB KIT

0.1 mol/L solutions of:

| | | | |
|---|---|---|---|
| 1. | KSCN | Potassium thiocyanate | |
| 2. | KCl | Potassium chloride | |
| 3. | NaSCN | Sodium thiocyanate | spot plates (white or colourless) |
| 4. | $Fe(NO_3)_3$ | Iron(III) nitrate | crayon pencil |
| 5. | $FeCl_3$ | Iron(III) chloride | glass plate (10 cm X 10 cm) |
| 6. | $Cu(NO_3)_2$ | Copper(II) nitrate | eye droppers |

## III. PROBLEM

Some combinations of pairs of the above solutions produce a deep red coloured solution due to the reaction between two of the ions present for form a complex ion which is this colour.

Using only the materials in the SPECIAL LAB KIT design an experiment to identify the pair of ions which react to form the coloured species.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the examiner has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The examiner will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated. You will be given a complete procedure to follow unless you have presented a procedure which has been evaluated as complete and workable.

VII. EVALUATION SCHEME (Total possible score.......25)

DESIGN (15 marks)

| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) |
|---|---|---|
| 1. ____ | 1. ____ | 1. ____ |
| 2. ____ | 2. ____ | 2. ____ |
| 3. ____ | 3. ____ | 3. ____ |
| 4. ____ | 4. ____ | 4. ____ |
| 5. ____ | 5. ____ | 5. ____ |

PERFORMANCE (10 marks)

| | |
|---|---|
| Correct identification | |
| of ion No.1 | 4 |
| of ion No.2 | 3 |
| Correct combinations of solutions that produce a red colour | 3 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

Make a table on your worksheet where you can record your observations for each pair of solutions combined. The following table lists all the combinations of solutions possible.

| | Solution 1 | ions | | Solution 2 | ions | |
|---|---|---|---|---|---|---|
| (i) | potassium thiocyanate | $K^+$ | $SCN^-$ | potassium chloride | $K^+$ | $Cl^-$ |
| (ii) | potassium thiocyanate | $K^+$ | $SCN^-$ | sodium thiocyanate | $Na^+$ | $SCN^-$ |
| (iii) | potassium thiocyanate | $K^+$ | $SCN^-$ | iron(III) nitrate | $Fe^{3+}$ | $NO_3^-$ |
| (iv) | potassium thiocyanate | $K^+$ | $SCN^-$ | iron(III) chloride | $Fe^{3+}$ | $Cl^-$ |
| (v) | potassium thiocyanate | $K^+$ | $SCN^-$ | copper(II) nitrate | $Cu^{2+}$ | $NO_3^-$ |
| (vi) | potassium chloride | $K^+$ | $Cl^-$ | sodium thiocyanate | $Na^+$ | $SCN^-$ |
| (vii) | potassium chloride | $K^+$ | $Cl^-$ | iron(III) nitrate | $Fe^{3+}$ | $NO_3^-$ |
| (viii) | potassium chloride | $K^+$ | $Cl^-$ | iron(III) chloride | $Fe^{3+}$ | $Cl^-$ |
| (ix) | potassium chloride | $K^+$ | $Cl^-$ | copper(II) nitrate | $Cu^{2+}$ | $NO_3^-$ |
| (x) | sodium thiocyanate | $Na^+$ | $SCN^-$ | iron(III) nitrate | $Fe^{3+}$ | $NO_3^-$ |
| (xi) | sodium thiocyanate | $Na^+$ | $SCN^-$ | iron(III) chloride | $Fe^{3+}$ | $Cl^-$ |
| (xii) | sodium thiocyanate | $Na^+$ | $SCN^-$ | copper(II) nitrate | $Cu^{2+}$ | $NO_3^-$ |
| (xiii) | iron(III) nitrate | $Fe^{3+}$ | $NO_3^-$ | iron(III) chloride | $Fe^{3+}$ | $Cl^-$ |
| (xiv) | iron(III) nitrate | $Fe^{3+}$ | $NO_3^-$ | copper(II) nitrate | $Cu^{2+}$ | $NO_3^-$ |
| (xv) | iron(III) chloride | $Fe^{3+}$ | $Cl^-$ | copper(II) nitrate | $Cu^{2+}$ | $NO_3^-$ |

PROCEDURAL STEP No. 2

Record your observations on the following table:

| | KSCN | KCl | NaSCN | $Fe(NO_3)_3$ | $FeCl_3$ | $Cu(NO_3)_2$ |
|---|---|---|---|---|---|---|
| $Cu(NO_3)_2$ | (v) | (ix) | (xii) | (xiv) | (xv) | |
| $FeCl_3$ | (iv) | (viii) | (xi) | (xiii) | | |
| $Fe(NO_3)_3$ | (iii) | (vii) | (x) | | | |
| KCl | (i) | | | | | |
| KSCN | | | | | | |

Use this six-by-six table (shown above) to label a glass plate or spot plate. Do your experimentation on the plate. It will aid you during the analysis of your observations.

PROCEDURAL STEP No. 3

Combine samples of each of the pairs of solutions. You may use drops of each on a spot plate or in clean test tubes.

PROCEDURAL STEP No. 4

Record on your worksheet those combinations which produce a red colour.

PROCEDURAL STEP No. 5

Those combinations which produced a red colour should have one positive ion and one negative ion common to them all. Those ions in common are responsible for the red colour.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of CLUES is designed to lead the students to the procedure outlined in the Procedural Clue. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

Additional Suggestions

(a) Prepare a six-by-six matrix on the glass plate or the spot plate.

| | KSCN | KCl | NaSCN | $Fe(NO_3)_3$ | $FeCl_3$ | $Cu(NO_3)_2$ |
|---|---|---|---|---|---|---|
| $Cu(NO_3)_2$ | (v) | (ix) | (xii) | (xiv) | (xv) | |
| $FeCl_3$ | (iv) | (viii) | (xi) | (xiii) | | |
| $Fe(NO_3)_3$ | (iii) | (vii) | (x) | | | |
| KCl | (i) | | | | | |
| KSCN | | | | | | |

The necessary (and sufficient) tests are numbered as in Clue No. 4.

(b) The tests can be performed on a spot plate, a ruled glass plate or in test tubes.

(c) The student should use small quantities (drops) of reagents.

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) The iron(III) chloride and iron(III) nitrate solutions should have been acidified in order to prevent precipitation of hydrolysis products.

(b) If sodium thiocyanate, NaSCN, is not available then substitute potassium thiocyanate solution (with the sodium thiocyanate label).

(c) Provide sufficient test tubes, and distilled water so that students can rinse equipment easily.

**Procedural Step Model**

**PROBLEM NO. 5**

**Scoring Guide**

Student

Date

Score

A. **Experimental Design**
The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

B. **Observations**

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______
2. ______
3. ______
4. ______
5. ______
6 ______
7 ______
8 ______
9 ______
______

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## For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

**Experimental Design (15 marks)**

(Please indicate with a check mark the **procedural steps** designed correctly and the **procedural steps** given to the student)

**Steps Designed Correctly**

**Phase I**

1. ______
2. ______
3. ______
4. ______
5. ______

**Phase II**

1. ______
2. ______
3. ______
4. ______
5. ______

**Steps Given to the Student**

1. ______
2. ______
3. ______
4. ______
5. ______

**Performance (10 marks)**

(Please enter the appropriate mark in Space III)

| | |
|---|---|
| Correct identification | |
| of ion No. 1 | 4 |
| of ion No. 2 | 3 |
| Correct combinations of solutions that produce a red colour | 3 |

**Experimental Design**

**Phase I**
**No. of steps x 3**
○ I

**Phase II**
**No. of steps x 2**
○ II

**Performance**
○ III

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# Procedural Step Model
# PROBLEM NO. 6

## I. INTRODUCTION

One of the most important areas of Chemistry is "qualitative analysis", the identification of species using a variety of techniques. In this experiment you shall attempt to distinguish among four positive ions on the basis of their reactions with various other reagents.

## II. SPECIAL LAB KIT

Dropper bottles - each containing 0.2 mol/L solutions of:

| | | | | | |
|---|---|---|---|---|---|
| 1. | Lead (II) nitrate | $Pb(NO_3)_2$ | 5. | Sodium chloride | $NaCl$ |
| 2. | Barium nitrate | $Ba(NO_3)_2$ | 6. | Sodium sulphate | $Na_2SO_4$ |
| 3. | Zinc nitrate | $Zn(NO_3)_2$ | 7. | Sodium carbonate | $Na_2CO_3$ |
| 4. | Potassium nitrate | $KNO_3$ | 8. | Sodium nitrate | $NaNO_3$ |

Two "unknown" solutions each containing one of:
$Pb^{2+}$, $Ba^{2+}$, $Zn^{2+}$ or $K^+$ ions.
Spot plates (black and white)
Crayon (wax) pencil

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to identify which one of the four positive ions is present in each of the unknown solutions.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design. Predict the observations you expect to make; explain how these observations will be used to identify the four positive ions.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated. You will be given a complete procedure to follow unless you have presented a procedure which has been evaluated as [ complete and workable.

## VII. EVALUATION SCHEME (Total possible score.......25)

| DESIGN (15 marks) | | | PERFORMANCE (10 marks) | |
|---|---|---|---|---|
| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) | | |
| 1. ____ | 1. ____ | 1. ____ | Correct scheme for analysis | 3 |
| 2. ____ | 2. ____ | 2. ____ | | |
| 3. ____ | 3. ____ | 3. ____ | Correct identity of unknown no. 1 | 4 |
| 4. ____ | 4. ____ | 4. ____ | Correct identity of unknown no. 2 | 3 |
| 5. ____ | 5. ____ | 5. ____ | | |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

Some combinations of ions produce precipitates when combined in the same solution.

Make a list of the possible combinations of solutions on your work sheet.

### PROCEDURAL STEP No. 2

1. Combine samples of the lead(II) nitrate solution with each of the sodium chloride, sodium sulphate and sodium carbonate solutions. You may use a spot plate, test tubes or the glass plate for the tests.
2. Repeat with the barium nitrate solution.
3. Repeat with the zinc nitrate solution.
4. Repeat with the potassium nitrate solution.

### PROCEDURAL STEP No. 3

Indicate on your work sheet, the combinations which form a precipitate.

### PROCEDURAL STEP No. 4

1. Combine samples of UNKNOWN No. 1 with each of the sodium chloride, sodium sulphate and sodium carbonate solutions. You may use a spot plate, test tubes or the glass plate for the tests.
2. Repeat with samples of UNKNOWN No. 2

### PROCEDURAL STEP No. 5

Compare the observations made with the unknowns with the observations made with the four "known" solutions.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The teacher is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The teacher has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions

(a) Determine, using the known solutions, the solubilities of the various "unknown" ions; repeat with the unknowns

| | | | |
|---|---|---|---|
| Insoluble | $PbCl_2$ | | |
| | $PbSO_4$ | $BaSO_4$ | |
| | $PbCO_3$ | $BaCO_3$ | $ZnCO_3$ |
| Soluble | KCl | $ZnCl_2$ | $BaCl_2$ |
| | $K_2SO_4$ | $ZnSO_4$ | |
| | $K_2CO_3$ | | |

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Give each student two (2) different unknown samples - each in a stoppered, labelled test tube.

(b) Provide a variety of different unknowns around the laboratory.

(c) Number the unknowns consecutively from 1, 2, 3 ......

(d) The black spot plates are very useful so that white precipitates can be observed easily.

(e) Test the solutions before use by the students. Concentrations (within limits) are important for the appropriate precipitates to form.

(f) The sodium nitrate solution is not necessary in order to solve the problem.

**Procedural Step Model**
**PROBLEM NO. 6**

## Scoring Guide

Student ______

Date ______

Score ______

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5 ____________________

6 ____________________
7 ____________________
8. ____________________
9. ____________________
____________________

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## For Teacher's Use Only

### Alternate Solution(s)

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

### Experimental Design (15 marks)

(Please indicate with a check mark the **procedural steps** designed correctly and the **procedural steps** given to the student)

**Steps Designed Correctly**

**Phase I**

1 ______
2. ______
3 ______
4 ______
5 ______

**Phase II**

1. ______
2. ______
3. ______
4. ______
5. ______

**Steps Given to the Student**

1. ______
2. ______
3. ______
4. ______
5. ______

### Performance (10 marks)

(Please enter the appropriate mark in Space III)

| | |
|---|---|
| Correct scheme for analysis | 3 |
| Correct identity of unknown no. 1 | 4 |
| Correct identity of unknown no. 2 | 3 |

### Experimental Design

**Phase I**
**No. of steps x 3**

○ I

**Phase II**
**No. of steps x 2**

○ II

**Performance**

○ III

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# Procedural Step Model PROBLEM NO. 7

## I. INTRODUCTION

Many substances decompose when heated. It is useful for the chemist to know the products of the decomposition reactions.

## II. SPECIAL LAB KIT

cobalt(II) nitrate hexahydrate (solid), $Co(NO_3)_2 \cdot 6H_2O(s)$
concentrated nitric acid
fume hood or fume vent
litmus paper (red and blue)
cobalt chloride test paper
copper turnings

## III. PROBLEM

Cobalt nitrate hexahydrate, $Co(NO_3)_2 \cdot H_2O$ decomposes when heated. Four possible decomposition reations are listed below. In each case the states of matter are indicated.

| | solid | | solid | | gas | | gas | | gas |
|---|---|---|---|---|---|---|---|---|---|
| (i) | $3Co(NO_3)_2 \cdot 6H_2O$ | $\rightarrow$ | $Co_3N_2$ | + | $4NO_2$ | + | $5O_2$ | + | $18H_2O$ |
| (ii) | $2Co(NO_3)_2 \cdot 6H_2O$ | $\rightarrow$ | $2CoO$ | + | $4NO_2$ | + | $O_2$ | + | $12H_2O$ |
| (iii) | $3Co(NO_3)_2 \cdot 6H_2O$ | $\rightarrow$ | $Co_3N_2$ | + | $4NO$ | + | $7O_2$ | + | $18H_2O$ |
| (iv) | $Co(NO_3)_2 \cdot 6H_2O$ | $\rightarrow$ | $CoO$ | + | $N_2$ | + | $5H_2O_2$ | + | $H_2O$ |

Using only the materials in the SPECIAL LAB KIT design an experiment to identify the equation which correctly illustrates the thermal decomposition of cobalt(II) nitrate hexahydrate. As a preliminary step heat a sample (5 mm depth) in a test tube and observe carefully.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

CAUTION: All experimental work for this problem must be performed in a well-vented area. The teacher must approve the work area.

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated You will be given a complete procedure to follow unless you have presented a procedure which has been evaluated as complete and workable.

## VII. EVALUATION SCHEME (Total possible score.......25)

DESIGN (15 marks)

| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) |
|---|---|---|
| 1. ____ | 1. ____ | 1. ____ |
| 2. ____ | 2. ____ | 2. ____ |
| 3. ____ | 3. ____ | 3. ____ |
| 4. ____ | 4. ____ | 4. ____ |
| 5. ____ | 5. ____ | 5. ____ |

PERFORMANCE (10 marks)

| | |
|---|---|
| Correct equation | 10 |
| Three products correct | 6 |
| Two products correct | 1 |
| Less than two products correct | 0 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

Heat a small sample of the cobalt nitrate hexahydrate in a test tube.

### PROCEDURAL STEP No. 2

1. Test the products evolved with cobalt chloride paper and with a glowing splint. Cobalt chloride paper turns pink in water.
2. Compare the colour of the gas produced by the reaction of copper with nitric acid and the gas produced by the heating of the cobalt nitrate hexahydrate.

Caution: The gas is poisonous; work in a well vented area only.

### PROCEDURAL STEP No. 3

1. Weigh an empty crucible. Place about 10 g of cobalt nitrate hexahydrate in the crucible and weigh again.
2. Heat the crucible until no further changes in the materials are evident.
3. Allow the crucible to cool to room temperature and re-weigh.

### PROCEDURAL STEP No. 4

1. Determine the weight of the residue.
2. Calculate the number of moles of residue.

$$\text{No. of moles of } Co(NO_3)_2 \cdot 6H_2O = \frac{\text{g of } Co(NO_3)_2 \cdot 6H_2O}{291}$$

$$\text{No. of moles of } Co_3N_2 = \frac{\text{g of residue}}{205}$$

$$\text{No. of moles of } CoO = \frac{\text{g of residue}}{75}$$

NOTE:

1 mol of $CoO$ is produced from 1 mol of $Co(NO_3)_2 \cdot 6H_2O$

1 mol of $Co_3N_2$ is produced from 3 mol of $Co(NO_3)_2 \cdot 6H_2O$

### PROCEDURAL STEP No. 5

Compare the number of moles of residue with the initial number of moles of cobalt nitrate hexahydrate that you heated. The amount of cobalt in the residue is the same as in the sample.

% Co in $Co(NO_3)_2 \cdot 6H_2O$ = 22%

% Co in $Co(NO_3)_2 \cdot 6H_2O$ = 22%

% Co in $Co_3N_2$ = 86%

% Co in $CoO$ = 79%

The mass of 1 mol of $Co(NO_3)_2 \cdot 6H_2O$ is 291 g.

The mass of 1 mol of $Co_3N_2$ is 205 g.

The mass of 1 mol of $CoO$ is 75 g.

Using the information shown above determine the identity of the residue and then determine the correct equation.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The teacher is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The teacher has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions

(a) Heat a small sample of $Co(NO_3)_2 \cdot 6H_2O$ in a test tube to obtain some qualitative observations.

(b) The presence of water can be verified by the cobalt chloride test. (Equation No. 3 is eliminated).

(c) The brownish-red gas is the same as that produced in the reaction between copper and nitric acid ($NO_2$). (Equation No. 4 is eliminated)

The identity of the brownish-red gas is not necessary in order to eliminate equation No. 4. The students should know that neither nitrogen ($N_2$) nor oxygen ($O_2$) is coloured.

(d) A positive "glowing splint" test should be verification of the presence of oxygen.

(e) Heat a larger sample (10 g) of the cobalt nitrate hexahydrate in a crucible. Continue heating until there is no further change.

The weight of the residue can be used to show that the residue is CoO rather than $Co_3N_2$.

$$\frac{\text{g of residue}}{75} = \text{No. of moles of CoO}$$

$$\frac{\text{g of residue}}{205} = \text{No. of moles of } Co_3N$$

If: No. of mol of CoO = No. of mol of $Co(NO_3)_2 \cdot 6H_2O$
Then the residue is CoO.

If: No. of mol of CoO = 1/3 No. of moles of $Co(NO_3)_2 \cdot 6H_2O$
Then the residue is $Co_3N$.

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Students MUST be supervised carefully; $NO_2$ is poisonous. Allow the students to work only in a fume hood or in an exceptionally well-vented area.

(b) This may be a more challenging problem than some others; give this problem to the more able students who may respond positively to the greater challenge.

(c) Provide the sample of cobalt(II) nitrate hexahydrate in a labelled test tube. Provide at least 15 g of the sample.

(d) Only very careful work will allow the students to distinguish between the number of moles of CoO and the number of moles of $Co_3N_2$ when compared with the number of moles of cobalt(II) nitrate hexahydrate used in the experiment.

**Procedural Step Model**

**PROBLEM NO. 7**

**Scoring Guide**

Student ____________

Date ____________

Score ____________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
6. ______________________
7. ______________________
8. ______________________
9. ______________________

______________________

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## For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

**Experimental Design (15 marks)**

(Please indicate with a check mark the **procedural steps** designed correctly and the **procedural steps** given to the student)

**Performance (10 marks)**

(Please enter the appropriate mark in Space III)

| | |
|---|---|
| Correct equation | 10 |
| Three products correct | 6 |
| Two products correct | 1 |
| Less than two products correct | 0 |

| Steps Designed Correctly | | Steps Given to the Student |
|---|---|---|
| **Phase I** | **Phase II** | |
| 1. ______ | 1. ______ | 1. ______ |
| 2 ______ | 2 ______ | 2. ______ |
| 3. ______ | 3. ______ | 3 ______ |
| 4 ______ | 4. ______ | 4. ______ |
| 5. ______ | 5 ______ | 5. ______ |

**Experimental Design**

| Phase I<br>No. of steps x 3 | Phase II<br>No. of steps x 2 | Performance |
|---|---|---|
| ○ I | ○ II | ○ III |

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# Procedural Step Model PROBLEM NO. 8

## I. INTRODUCTION

Chemists often find it necessary to find the concentration of an acidic or basic solution.

## II. SPECIAL LAB KIT

Solution of unknown concentration
NaOH, sodium hydroxide solution, 0.200 mol/L
HCl, hydrochloric acid solution, 0.200 mol/L
(the actual concentrations are noted on the bottles)
litmus paper
bromothymol blue solution
phenolphthalein solution
magnesium ribbon

## III. PROBLEM

The unknown solution provided to you is either an acidic or basic solution of unknown concentration. Before proceeding with your Design determine, experimentally, whether your solution is acidic or basic.

Using only the materials in the SPECIAL LAB KIT design an experiment to determine the concentration of the solution. Express the concentration in terms of moles of hydrogen ion, $H^+(aq)$ or moles of hydroxyl ion, $OH^-(aq)$ per litre of solution.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated You will be given a complete procedure to follow unless you have presented a procedure which has been evaluated as complete and workable.

## VII. EVALUATION SCHEME (Total possible score.......25)

### DESIGN (15 marks)

| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) |
|---|---|---|
| 1. ____ | 1. ____ | 1. ____ |
| 2. ____ | 2. ____ | 2. ____ |
| 3. ____ | 3. ____ | 3. ____ |
| 4. ____ | 4. ____ | 4. ____ |
| 5. ____ | 5. ____ | 5. ____ |

### PERFORMANCE (10 marks)

1. Class of solution 2
2. Calculations 2
3. Concentration Marks are awarded on the basis of the % error in the experimental data.

| Experimental Error | |
|---|---|
| >25% | 0 |
| 15-25% | 1 |
| 5-15% | 2 |
| 1- 5% | 4 |
| < 1% | 6 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

ECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

Determine the acidic and basic colours of a given indicator, bromothymol blue, by adding two drops of bromothymol blue solution to individual test tubes containing samples of the sodium hydroxide and hydrochloric acid solutions.

### PROCEDURAL STEP No. 2

1. Use the same indicator, bromothymol blue, to determine if the unknown is an acid or a base.
2. Use a pipet or a graduated cylinder to transfer 25 mL of the unknown solution to an Erlenmeyer flask.
3. Add 3 drops of bromothymol blue solution to the unknown.

### PROCEDURAL STEP No. 3

1. If the unknown solution is blue -

(i) Using either a graduated pipet or a buret add hydrochloric acid solution (0.2 mol/L) until the solution turns green.

ii) Measure the volume of hydrochloric acid solution required to carry out the neutralization.

2. If the unknown solution is yellow -

(i) Using either a graduated pipet or a buret, add sodium hydroxide solution (0.2 mol/L) until the solutionn turns green.

(ii) Measure the volume of sodium hydroxide solution required to carry out the neutralization.

### PROCEDURAL STEP No. 4

Repeat step 5 in order to obtain more precise data.

### PROCEDURAL STEP No. 5

Calculations:

(i) Calculate the number of moles of acid/base used to neutralize the 25 mL of unknown sample.

(ii) No. of moles of acid ($H^+$) = Volume (L) x Concentration (mol/L).

(iii) No. of moles of acid ($H^+$) = No.of moles of base ($OH^-$).

(iv) Calculate the number of moles of $H^+$ or $OH^-$ in the 25 mL sample of the unknown.

(v) Calculate the number of moles of $H^+$ or $OH^-$ in 1 L of the unknown solution.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The teacher is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The teacher has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Provide known solutions of sodium hydroxide and hydrochloric acid with the concentrations shown on the labels. Quote concentrations to three significant digits (0.211 mol/L, for example).

(b) Do NOT provide the same known solutions to all students. Vary the concentrations of the known samples.

(c) Prepare a variety of acidic and basic unknowns

**Procedural Step Model**
**PROBLEM NO. 8**

**Scoring Guide** PSM.8(5)

Student ______________________

Date ______________________

Score ______________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1 ______________________ 6. ______________________
2. ______________________ 7. ______________________
3. ______________________ 8. ______________________
4 ______________________ 9. ______________________
5. ______________________ ______________________

---

### For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution

☐ 5

### Experimental Design (15 marks)

(Please indicate with a check mark the **procedural** steps designed correctly and the **procedural steps** given to the student)

| Steps Designed Correctly | | Steps Given to the Student |
|---|---|---|
| Phase I | Phase II | |
| 1. ______ | 1. ______ | 1. ______ |
| 2. ______ | 2. ______ | 2. ______ |
| 3. ______ | 3. ______ | 3. ______ |
| 4. ______ | 4. ______ | 4. ______ |
| 5. ______ | 5. ______ | 5. ______ |

### Performance (10 marks)

(Please enter the appropriate mark in Space III)

| | |
|---|---|
| Class of solution | 2 |
| Calculations | 2 |

Concentration Marks are awarded on the basis of the % error in the experimental data.

| Experimental Error | |
|---|---|
| >25% | 0 |
| 15-25% | 1 |
| 5-15% | 2 |
| 1- 5% | 4 |
| < 1% | 6 |

### Experimental Design

Phase I
No. of steps x 3
○ I

Phase II
No. of steps x 2
○ II

**Performance**
○ III

---

Total Score ○ I + ○ II + ○ III = ⬡ TOTAL

# Procedural Step Model
# PROBLEM NO. 9

## I. INTRODUCTION

The passage of an electrical current through an aqueous solution may result in the decomposition of the dissolved species or of the solvent. Chemists are frequently faced with the problem of identifying the products of electrolysis.

## II. SPECIAL LAB KIT

DC power supply
leads with alligator clips
U-tube
trichlorotrifluoroethane
eye droppers
nitric acid
unknown solution
rubber tubing
carbon rods
zinc strips
copper strips
aluminum strips
rubber stoppers
litmus paper
wood splints
limewater

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to identify the materials that are produced when the unknown solution is electrolyzed.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated. You will be given a complete procedure to follow unless you have presented a procedure which has been evaluated as complete and workable.

## VII. EVALUATION SCHEME (Total possible score.......25)

DESIGN (15 marks)

| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) |
|---|---|---|
| 1. ____ | 1. ____ | 1. ____ |
| 2. ____ | 2. ____ | 2. ____ |
| 3. ____ | 3. ____ | 3. ____ |
| 4. ____ | 4. ____ | 4. ____ |
| 5. ____ | 5. ____ | 5. ____ |

PERFORMANCE (10 marks)

| | |
|---|---|
| 1. Identity of product No. 1 | 4 |
| 2. Identity of product No. 2 | 3 |
| 3. Electrode identification. | 3 |

NOTE

(1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

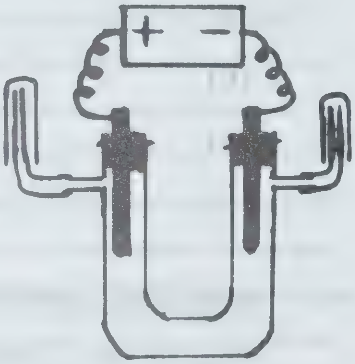
1. Connect the output terminals of the power supply to the carbon electrodes.

2. Place short lengths of rubber tubing on the side arms of the U-tube.

### PROCEDURAL STEP No. 2

1. Invert small test tubes over the lengths of rubber tubing.

2. Activate the power supply and observe.



### PROCEDURAL STEP No. 3

Test the gas(es) collected with a
  (a) burning splint
  (b) glowing splint
  (c) few drops of trichlorotrifluoroethane

### PROCEDURAL STEP No. 4

1. Observe any solid that accumulates on the electrode(s).

2. Immerse the tip of the electrodes in a few mL of concentrated nitric acid in a small test tube.

### PROCEDURAL STEP No. 5

The colour of the solution and the gases formed may be an indication of the presence and identity of a particular solid product.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The teacher is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The teacher has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Sample "unknown" solutions that may be used:

copper(II) chloride

copper(II) bromide

copper(II) iodide

sodium chloride

hydrochloric acid

magnesium bromide

potassium iodide

sodium bromide

(b) The solutions may all be coloured blue - to simulate a copper ion solution.

(c) Change the coding scheme for those candidates who are NOT in the laboratory at the same time. Students in the laboratory at the same time can have the same coding.

**Procedural Step Model**
**PROBLEM NO. 9**

**Scoring Guide** PSM.9(5)

Student ____________________

Date ____________________

Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1 ____________________
2. ____________________
3 ____________________
4. ____________________
5. ____________________
6. ____________________
7. ____________________
8. ____________________
9. ____________________
____________________

---

## For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

**Experimental Design (15 marks)**

(Please indicate with a check mark the **procedural steps** designed correctly and the **procedural steps** given to the student)

| Steps Designed Correctly<br>Phase I | Steps Designed Correctly<br>Phase II | Steps Given to the Student |
|---|---|---|
| 1 ______ | 1. ______ | 1. ______ |
| 2 ______ | 2. ______ | 2. ______ |
| 3 ______ | 3 ______ | 3. ______ |
| 4 ______ | 4 ______ | 4. ______ |
| 5 ______ | 5 ______ | 5. ______ |

**Performance (10 marks)**

(Please enter the appropriate mark in Space III)

| | |
|---|---|
| Identity of product No. 1 | 4 |
| Identity of product No. 2 | 3 |
| Electrode identification. | 3 |

**Experimental Design**

**Phase I**
**No. of steps x 3**

○ I

**Phase II**
**No. of steps x 2**

○ II

**Performance**

○ III

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# Procedural Step Model PROBLEM NO. 10

## I. INTRODUCTION

A characteristic property of a substance is its solubility in water. Sometimes the chemist must devise different methods to determine the solubilities of different substances.

## II. SPECIAL LAB KIT

10 mL graduated cylinders
medicine droppers
conductivity apparatus
porcelain dish
calcium hydroxide (solid)
calcium chloride solution (0.100 mol/L)
sodium carbonate solution (0.100 mol/L)
ammonium chloride solution (0.100 mol/L)
ammonium carbonate solution (0.100 mol/L)
thermometer (-10° - 110°C)
saturated calcium hydroxide solution (limewater)
$H_2SO_4$ (0.025 mol/L)
litmus paper
phenolphthalein solution
bromothymol blue solution
HCl (0.050 mol/L)
pipets
centigram balance
filter paper
buret
soda straws

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to determine the solubility (grams of calcium hydroxide per litre of solution) of calcium hydroxide in water.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design. Predict the observations you expect to make. Explain how you will use these observations to determine the solubilty of calcium hydroxide.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated You will be given a complete procedure to follow unless you have presented a procedure which has been evaluated as complete and workable.

## VII. EVALUATION SCHEME (Total possible score.......25)

### DESIGN (15 marks)

| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) |
|---|---|---|
| 1. ____ | 1. ____ | 1. ____ |
| 2. ____ | 2. ____ | 2. ____ |
| 3. ____ | 3. ____ | 3. ____ |
| 4. ____ | 4. ____ | 4. ____ |
| 5. ____ | 5. ____ | 5. ____ |

### PERFORMANCE (10 marks)

1. Marks are awarded on the basis of the % error in the experimental data.

| Experimental Error | |
|---|---|
| >50% | 0 |
| 30-50% | 1 |
| 20-30% | 3 |
| 10-20% | 4 |
| <10% | 6 |

2. Calculations-

| | |
|---|---|
| a) Step 1 | 2 |
| b) Step 2 | 1 |
| c) Step 3 | 1 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

1. Use a pipet to transfer 25 mL of calcium hydroxide solution to an Erlenmeyer flask.

2. Add three drops of bromothymol blue solution to the calcium hydroxide solution.

### PROCEDURAL STEP No. 2

1. Use a buret to add sulfuric acid solution (0.100 mol/L) to the the calcium hydroxide solution until the indicator turns green.

2. Measure and record the volume of sulphuric acid solution consumed.

3. Repeat the procedure using a second 25 mL sample of calcium hydroxide solution.

### PROCEDURAL STEP No. 3

Calculate the number of moles of sulfuric acid consumed.
No. of moles of $H_2SO_4$ = Volume (L) x Concentration (mol/L)

### PROCEDURAL STEP No. 4

1. Calculate the number of moles of calcium hydroxide in the original sample.

2. No. of moles of $Ca(OH)_2$ = No. of moles of $H_2SO_4$

### PROCEDURAL STEP No. 5

1. Determine the solubility of calcium hydroxide in g/L.
2. Mass of $Ca(OH)_2$ = Volume (L) x Mass of 1 mole of $Ca(OH)_2$

## SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The teacher is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The teacher has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions
(a)
(b)
(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) The unknown samples must be freshly prepared to avoid precipitation of the carbonate through reaction with carbon dioxide.
(b) The concentration of the various test solutions must be quoted to at least two significant digits.
(c) Students may be given solutions of barium hydroxide or strontium hydroxide in place of the calcium hydroxide. In this case the student must be told the identity of the "unknown" sample.
Appropriate changes would have to be made in Clue No. 4 as well as in the SPECIAL LAB KIT.
(d) Students must be familiar with the use of pipets and burets.
(e) The avenue is available for students to perform the titrations with medicine droppers.
(f) The teacher must recognize, in evaluating the student data, that the solubility of a solute in a given solvent may be a function of temperature.
(g) The units g/L were selected for this problem. The units g of solute per 100 g of solvent are recognized in problem 11.
(h) Published solubility data (Handbok of Chemistry and Physics).

| Temperature | Solubility (g/L) | | |
|---|---|---|---|
| | $Ca(OH)_2$ | $Ba(OH)_2$ | $Sr(OH)_2$ |
| $0^{\circ}C$ | 1.85 g | 56 g | 4.1 g |
| $100^{\circ}C$ | 0.77 g | 947 g | 218.3 g |

A preliminary titration by the teacher can be used to approximate the solubility at room temperature.

**Procedural Step Model**
**PROBLEM NO. 10**

**Scoring Guide** PSM.10(5)

Student ____________________

Date ____________________

Score ____________________

### Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

### B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6 ______________________________
7. ______________________________
8. ______________________________
9. ______________________________
______________________________

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## For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

**Experimental Design (15 marks)**

(Please indicate with a check mark the **procedural steps** designed correctly and the **procedural steps** given to the student)

| Steps Designed Correctly | | Steps Given to the Student |
|---|---|---|
| **Phase I** | **Phase II** | |
| 1. ______ | 1. ______ | 1. ______ |
| 2. ______ | 2. ______ | 2. ______ |
| 3. ______ | 3. ______ | 3. ______ |
| 4. ______ | 4. ______ | 4. ______ |
| 5. ______ | 5. ______ | 5. ______ |

**Performance (10 marks)**

(Please enter the appropriate mark in Space III)

Marks are awarded on the basis of the % error in the experimental data.

| Fxperimental | Error |
|---|---|
| >50% | 0 |
| 30-50% | 1 |
| 20-30% | 3 |
| 10-20% | 4 |
| <10% | 6 |

Calculations-

| | |
|---|---|
| a) Step 1 | 2 |
| b) Step 2 | 1 |
| c) Step 3 | 1 |

**Experimental Design**

**Phase I**
No. of steps x 3
○ I

**Phase II**
No. of steps x 2
○ II

**Performance**
○ III

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

**Procedural Step Model**
**PROBLEM NO. 11**

## I. INTRODUCTION

A characteristic property of a substance is its solubility in water. Sometimes the chemist must devise different methods to determine the solubilities of different substances.

## II. SPECIAL LAB KIT

10 mL graduated cylinders
medicine droppers
conductivity apparatus
porcelain dish
calcium hydroxide (solid)
calcium chloride solution (0.100 mol/L)
sodium carbonate solution (0.100 mol/L)
ammonium chloride solution (0.100 mol/L)
ammonium carbonate solution (0.100 mol/L)
thermometer $(-10^{\circ} - 110^{\circ}C)$
saturated calcium hydroxide solution (limewater)
$H_2SO_4$ (0.025 mol/L)
litmus paper
phenolphthalein solution
bromothymol blue solution
HCl (0.050 mol/L)
pipets
centigram balance
filter paper
buret
soda straws

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to determine the solubility (g of solute per 100 g of solvent) of calcium hydroxide in water.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design. Predict the observations you expect to make. Explain how you will use these observations to determine the solubilty of calcium hydroxide.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated You will be given a complete procedure to follow unless you have presented a procedure which has been evaluated as complete and workable.

## VII. EVALUATION SCHEME (Total possible score.......25)

### DESIGN (15 marks)

| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) |
|---|---|---|
| 1. ____ | 1. ____ | 1. ____ |
| 2. ____ | 2. ____ | 2. ____ |
| 3. ____ | 3. ____ | 3. ____ |
| 4. ____ | 4. ____ | 4. ____ |
| 5. ____ | 5. ____ | 5. ____ |

### PERFORMANCE (10 marks)

1. Marks are awarded on the basis of the % error in the experimental data.

2. Experimental Error

| | |
|---|---|
| >50% | 0 |
| 30-50% | 1 |
| 20-30% | 2 |
| 10-20% | 3 |
| <10% | 5 |

3. Calculations

| | |
|---|---|
| a) Step 1 | 2 |
| b) Step 2 | 1 |
| c) Step 3 | 1 |
| d) Step 4 | 1 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

1. Find the mass of an Erlenmeyer flask.
2. Use a pipet to transfer 25 mL of calcium hydroxide solution to an Erlenmeyer flask.
3. Find the mass of the flask and the sample solution.

### PROCEDURAL STEP No. 2

1. Add three drops of bromothymol blue solution to the calcium hydroxide solution.
2. Use a buret to add sulfuric acid solution (0.100 mol/L) to the calcium hydroxide solution until the indicator turns green.
3. Measure and record the volume of sulphuric acid solution consumed.
4. Repeat the procedure using a second 25 mL sample of calcium hydroxide solution.

### PROCEDURAL STEP No. 3

1. Calculate the number of moles of sulfuric acid consumed.
2. No. of moles of sulfuric acid = Volume (L) x Concentration (mol/L)

### PROCEDURAL STEP No. 4

1. Calculate the number of moles of calcium hydroxide in the original sample.
2. No. of moles of calcium hydroxide = No. of moles of sulfuric acid

### PROCEDURAL STEP No. 5

1. Calculate the mass of calcium hydroxide dissolved in the 25 mL sample of solution.
2. Mass of calcium hydroxide = $V_{(L)}$ x Mass of 1 mol of $Ca(OH)_2$
3. Mass of water = (Mass of sample) - (Mass of calcium hydroxide)

## IX. SUGGESTED PROCEDURES

There are many^procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The teacher is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The teacher has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions
(a)
(b)
(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) The unknown samples must be freshly prepared to avoid precipitation of the carbonate through reaction with carbon dioxide.
(b) The concentration of the various test solutions must be quoted to at least two significant digits.
(c) Students may be given solutions of barium hydroxide or strontium hydroxide in place of the calcicm hydroxide. In this case the student must be told the identity of the "unknown" sample.
Appropriate changes would have to be made to Clue No. 5 as well as in the SPECIAL LAB KIT.
(d) Students must be familiar with the use of pipets and burets.
(e) The avenue is available for students to perform the titrations with medicine droppers.
(f) The examiner must recognize, in evaluating the student data, that the solubility of a solute in a given solvent may be a function of temperature.
(g) The units g/100 g of a solvent were selected for this problem. The units g/L are recognized in problem 10.
(h) Published solubility data (Handbook of Chemistry and Physics).

| Temperature | Solubility (g/L)<br>(g/100 g of water) | | |
|---|---|---|---|
| | $Ca(OH)_2$ | $Ba(OH)_2$ | $Sr(OH)_2$ |
| 0°C | 0.185 g | 5.6 g | 4.1 g |
| 100°C | 0.077 g | 94.7 g | 21.83 g |

A preliminary titration by the teacher can be used to approximate the solubility at room temperature.

## Procedural Step Model

## PROBLEM NO. 11

**Scoring Guide**

Student ____________________

Date ____________________

Score ____________________

### A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

### B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1 ____________________
2. ____________________
3. ____________________
4 ____________________
5 ____________________
6. ____________________
7. ____________________
8. ____________________
9. ____________________
____________________

---

### For Teacher's Use Only

### Alternate Solution(s)

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

### Experimental Design (15 marks)

(Please indicate with a check mark the **procedural steps** designed correctly and the **procedural steps** given to the student)

| Steps Designed Correctly<br>Phase I | Steps Designed Correctly<br>Phase II | Steps Given to the Student |
|---|---|---|
| 1 ____ | 1 ____ | 1 ____ |
| 2 ____ | 2 ____ | 2. ____ |
| 3 ____ | 3 ____ | 3 ____ |
| 4 ____ | 4 ____ | 4 ____ |
| 5 ____ | 5 ____ | 5 ____ |

### Performance (10 marks)

(Please enter the appropriate mark in Space III)

Marks are awarded on the basis of the % error in the experimental data.

| Experimental Error | |
|---|---|
| >50% | 0 |
| 30-50% | 1 |
| 20-30% | 2 |
| 10-20% | 3 |
| <10% | 5 |

| Calculations | |
|---|---|
| a) Step 1 | 2 |
| b) Step 2 | 1 |
| c) Step 3 | 1 |
| d) Step 4 | 1 |

### Experimental Design

**Phase I**
No. of steps x 3

○ I

**Phase II**
No. of steps x 2

○ II

**Performance**

○ III

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# Procedural Step Model
# PROBLEM NO. 12

## I. INTRODUCTION

The chemist is frequently called upon to separate and identify the components of a mixture. The materials are frequently similar in colour and texture, but different in use and properties.

Calcium carbonate (limestone), $CaCO_3$, is used in crushed form in road building. In the laboratory it can be used as a substitute for marble chips to produce carbon dioxide.

Calcium chloride, $CaCl_2$, is used to dry the air in humid basements; $CaCl_2$ absorbs water vapour from the air.

Calcium hydroxide (slaked lime), $Ca(OH)_2$, mixed with water is used as whitewash. It can also be added to soil to counteract acidity.

## II. SPECIAL LAB KIT

calcium carbonate(s), $CaCO_3$
calcium hydroxide(s), $Ca(OH)_2$
calcium chloride(s), $CaCl_2$
bromothymol blue solution
hydrochloric acid, HCl, (0.200 mol/L)
silver nitrate solution (0.002 mol/L)
vial containing a mixture of calcium hydroxide and at least one of calcium carbonate and calcium chloride

litmus paper
buret
pipet
filter paper
funnel

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to determine the % (by mass) of calcium hydroxide in the mixture.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated You will be given a complete procedure to follow unless you have presented a procedure which has been evaluated as complete and workable.

## VII. EVALUATION SCHEME (Total possible score.......25)

DESIGN (15 marks)

| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) |
|---|---|---|
| 1. ____ | 1. ____ | 1. ____ |
| 2. ____ | 2. ____ | 2. ____ |
| 3. ____ | 3. ____ | 3. ____ |
| 4. ____ | 4. ____ | 4. ____ |
| 5. ____ | 5. ____ | 5. ____ |

PERFORMANCE (10 marks)

1. Marks are awarded on the basis of the % error in the experimental data.

| Experimental Error | |
|---|---|
| >50% | 0 |
| 30-50% | 2 |
| 20-30% | 4 |
| 10-20% | 5 |
| <10% | 7 |

2. Calculations 3

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

1. Determine the mass of the vial, contents and cap.
2. Empty approximately half of the contents of the vial into a 250 mL beaker containing 100 mL of water. Stir to dissolve as much of the sample as possible.
3. Determine the mass of the vial, cap and the remaining contents of the vial.

### PROCEDURAL STEP No. 2

Filter the mixture.

### PROCEDURAL STEP No. 3

Fill a buret with hydrochloric acid (0.200 mol/L) solution.

### PROCEDURAL STEP No. 4

1. Fill a buret with hydrochloric acid (0.200 mol/L) solution.
2. Add the hydrochloric acid solution until the colour of the solution changes from blue to green.
3. Repeat the procedure to obtain confirmatory data.

### PROCEDURAL STEP No. 5

Calculations:

(i) No. of moles of hydrochloric acid

$$= V_{(L)} \times \text{Concentration (mol/L)}$$

(ii) No. of moles of calcium hydroxide

$$= \frac{1}{2} \times \text{No. of moles of hydrochloric acid}$$

(iii) % calcium hydroxide

$$= \frac{\text{Mass of calcium hydroxide}}{\text{Mass of solid mixture}} \times 100\%$$

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The teacher is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The teacher has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Samples of the solid mixtures should be prepared by careful mixing with a mortar and pestle, of samples of known mass of the three solids.

(b) The % of $Ca(OH)_2$ should be different in the samples given to students who are in the laboratory at different times.

(c) The total sample size is not significant; the sample should not contain any more than 0.2 g of calcium hydroxide.

(d) The concentration of the hydrochloric acid should be given to three significant digits (0.137 mol/L, for example).

(e) The problem can be changed to any of the other alkaline earth hydroxides. Remember to take account of the water solubility of the hydroxides before deciding on the sample size.

**Procedural Step Model**
**PROBLEM NO. 12**

**Scoring Guide**

Student ____________________

Date ____________________

Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________________
2 ______________________
3 ______________________
4. ______________________
5 ______________________
6. ______________________
7. ______________________
8. ______________________
9. ______________________
______________________

---

### For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

**Experimental Design (15 marks)**

(Please indicate with a check mark the **procedural steps** designed correctly and the **procedural steps** given to the student)

| Steps Designed Correctly | | Steps Given to the Student |
|---|---|---|
| **Phase I** | **Phase II** | |
| 1 ______ | 1 ______ | 1. ______ |
| 2 ______ | 2. ______ | 2. ______ |
| 3 ______ | 3 ______ | 3. ______ |
| 4 ______ | 4 ______ | 4. ______ |
| 5 ______ | 5. ______ | 5. ______ |

**Performance (10 marks)**

(Please enter the appropriate mark in Space III)

Marks are awarded on the basis of the % error in the experimental data.

| Experimental Error | |
|---|---|
| >50% | 0 |
| 30-50% | 2 |
| 20-30% | 4 |
| 10-20% | 5 |
| <10% | 7 |
| Calculations | 3 |

**Experimental Design**

**Phase I**
**No. of steps x 3**
○ I

**Phase II**
**No. of steps x 2**
○ II

**Performance**
○ III

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

## Procedural Step Model PROBLEM NO. 13

### I. INTRODUCTION

It is frequently necessary to identify the contents of a series of unlabelled bottles.

### II. SPECIAL LAB KIT

spot plates
test tubes
2 groups of dropper bottles labelled I, II, III and X,Y,Z
Bottles I, II, III - contain 0.5 mol/L solutions of
    sodium carbonate solution
    sodium chloride solution
    sodium acetate solution

Bottles X, Y, Z - contain 0.5 mol/L solutions of
    hydrochloric acid solution
    lead nitrate solution
    potassium nitrate solution

### III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to identify the contents of each of the 6 bottles.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design. Predict the observations you expect to make; explain how you will use these observations to identify the six solutions.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

### IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated You will be given a complete procedure to follow unless you have presented a procedure which has been evaluated as complete and workable.

## VII. EVALUATION SCHEME (Total possible score.......25)

DESIGN (15 marks)

| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) |
|---|---|---|
| 1. ____ | 1. ____ | 1. ____ |
| 2. ____ | 2. ____ | 2. ____ |
| 3. ____ | 3. ____ | 3. ____ |
| 4. ____ | 4. ____ | 4. ____ |
| 5. ____ | 5. ____ | 5. ____ |

PERFORMANCE (10 marks)

| | |
|---|---|
| 6 labels correct | 10 |
| 5 labels correct | 8 |
| 4 labels correct | 6 |
| 3 labels correct | 3 |
| 2 labels correct | 2 |
| 1 label correct | 1 |
| 0 labels correct | 0 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

1. Place a few drops of solutions I, II and III in separate test tubes (or in spot plate depressions).
2. Prepare a "three by three" table of reaction possibilities.

### PROCEDURAL STEP No. 2

Add a few drops of solution X to each of solutions I, II and III.

### PROCEDURAL STEP No. 3

1. To fresh samples of I, II and III add samples of solution Y.
2. Repeat with solution Z.

### PROCEDURAL STEP No. 4

Only one of solutions X, Y, and Z will produce a precipitate.

### PROCEDURAL STEP No. 5

Only one of solution X, Y, and Z will produce an effervescent reaction. The gas is carbon dioxide.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The teacher is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The teacher has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Change the coding for students who are not in the laboratory at the same time.

(b) Change the identity of the materials used.

(c) The concentrations of the acid and the carbonate must be checked to see if a visible effervescence can easily be observed.

**Procedural Step Model**

**PROBLEM NO. 13**

**Scoring Guide**

Student ____________________

Date ____________________

Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________________ 6. ______________________
2. ______________________ 7. ______________________
3. ______________________ 8. ______________________
4. ______________________ 9. ______________________
5 ______________________ ______________________

---

## For Teacher's Use Only

### Alternate Solution(s)

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution. ☐ 5

### Experimental Design (15 marks)

(Please indicate with a check mark the **procedural steps** designed correctly and the **procedural steps** given to the student)

| Steps Designed Correctly | | Steps Given to the Student |
|---|---|---|
| **Phase I** | **Phase II** | |
| 1. ______ | 1. ______ | 1. ______ |
| 2. ______ | 2. ______ | 2. ______ |
| 3. ______ | 3. ______ | 3. ______ |
| 4 ______ | 4. ______ | 4. ______ |
| 5 ______ | 5 ______ | 5. ______ |

### Performance (10 marks)

(Please enter the appropriate mark in Space III)

| | |
|---|---|
| 6 labels correct | 10 |
| 5 labels correct | 8 |
| 4 labels correct | 6 |
| 3 labels correct | 3 |
| 2 labels correct | 2 |
| 1 label correct | 1 |
| 0 labels correct | 0 |

### Experimental Design

**Phase I**
**No. of steps x 3**
○ I

**Phase II**
**No. of steps x 2**
○ II

**Performance**
○ III

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# Procedural Step Model PROBLEM NO. 14

## I. INTRODUCTION

The chemist is frequently called upon to prepare and collect a given mass or volume of a pure substance.

## II. SPECIAL LAB KIT

balance
graduated pipet
medicine droppers
pipet bulbs
buret
graduated cylinder (250 mL)
bottle for the sodium hydroxide solution
hydrochloric acid solution (0.100 mol/L)
potassium hydroxide solution
sodium hydroxide solution
bromothymol blue solution
phenolphthalein solution
sodium hydrogen carbonate (s)

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to prepare 200 mL of sodium hydroxide solution containing 0.156 mol of sodium hydroxide per litre of solution.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated You will be given a complete procedure to follow unless you have presented a procedure which has been evaluated as complete and workable.

## VII. EVALUATION SCHEME (Total possible score.......25)

DESIGN (15 marks)

| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) |
|---|---|---|
| 1. ____ | 1. ____ | 1. ____ |
| 2. ____ | 2. ____ | 2. ____ |
| 3. ____ | 3. ____ | 3. ____ |
| 4. ____ | 4. ____ | 4. ____ |
| 5. ____ | 5. ____ | 5. ____ |

PERFORMANCE (10 marks)

1. Marks are awarded on the basis of the % error in the experimental data.
2. Concentration of the sodium hydroxide solution.

| Experimental Error | |
|---|---|
| >20% | 0 |
| 10-20% | 1 |
| 5-10% | 3 |
| 1- 5% | 5 |
| < 2% | 8 |

3. Volume of solutions

| Experimental Error | |
|---|---|
| >10% | 0 |
| 5-10% | 1 |
| < 5% | 2 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

1. Use a pipet to transfer 10 mL of the given sodium hydroxide solution to an Erlenmeyer flask.
2. Add 3 drops of bromothymol blue solution to the sodium hydroxide solution.

### PROCEDURAL STEP No. 2

1. Fill a buret with the hydrochloric acid solution.
2. Add hydrochloric acid until the bromothymol blue turns from blue to green.
3. Record the volume of hydrochloric acid solution consumed.

### PROCEDURAL STEP No. 3

1. Calculate the concentration, mol/L, of the sodium hydroxide solution (mol/L).

NOTE: No. of moles of HCl = No. of moles of NaOH

2. Calculate the number of moles of sodium hydroxide in 200 mL of solution containing 0.156 mol of NaOH per litre of solution.

### PROCEDURAL STEP No. 4

Calculate the volume ($V_1$) of the given sodium hydroxide solution which contains the number of moles of sodium hydroxide calculated above.

### PROCEDURAL STEP No. 5

1. Use a graduated pipet or cylinder to transfer the $V_1$ mL of sodium hydroxide solution to a graduated cylinder.
2. Add sufficient distilled water to make the total volume 200 mL.
3. Transfer the NaOH solution from the graduated cylinder to the storage bottle.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The teacher is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The teacher has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) The sodium hydroxide solution can be replaced by potassium hydroxide for different classes or students.

(b) Make certain that all pipet work is done with pipet bulbs.

(c) The sodium hydroxide should contain approximately 1.5 mol (60 g) of sodium hydroxide per litre of solution. Provide 50 mL of solution in the SPECIAL LAB KIT.

(d) The concentration of the hydrochloric acid solution should be quoted to three significant digits (0.100 mol/L for example).

(e) Prepare solutions of varying concentrations for students who are in the laboratory at different times.

Procedural Step Model

PROBLEM NO. 14

**Scoring Guide**

Student ____________________

Date ____________________

Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
6. ______________________
7. ______________________
8. ______________________
9. ______________________

______________________

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### For Teacher's Use Only

**Alternate Solution(s)**
Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐
5

**Experimental Design (15 marks)**
(Please indicate with a check mark the **procedural steps** designed correctly and the **procedural steps** given to the student)

**Steps Designed Correctly**

| **Phase I** | **Phase II** |
|---|---|
| 1. ____ | 1. ____ |
| 2. ____ | 2. ____ |
| 3 ____ | 3. ____ |
| 4. ____ | 4. ____ |
| 5. ____ | 5. ____ |

**Steps Given to the Student**

1. ____
2. ____
3. ____
4. ____
5. ____

**Performance (10 marks)**
(Please enter the appropriate mark in Space III)

Concentration of the sodium hydroxide solution.

| Experimental Error | |
|---|---|
| >20% | 0 |
| 10-20% | 1 |
| 5-10% | 3 |
| 1- 5% | 5 |
| < 2% | 8 |

Volume of solutions

| Experimental Error | |
|---|---|
| >10% | 0 |
| 5-10% | 1 |
| < 5% | 2 |

**Experimental Design**

**Phase I**
**No. of steps x 3**

○ I

**Phase II**
**No. of steps x 2**

○ II

**Performance**

○ III

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# Procedural Step Model PROBLEM NO. 15

## I. INTRODUCTION

Many commericial medicinal tablets react with water to release gases. The identity of the gas can be determined and verified both qualitatively and quantitatively.

## II. SPECIAL LAB KIT

- wood splints
- thermometer
- serum cap
- syringe assembly
- graduated cylinder
- 2 commercial tablets
- calcium hydroxide solution
- barometer
- plastic bags
- rubber stoppers
- length of glass tubing

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to identify and determine the molecular weight of the gas produced when the commercial tablet is added to water.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the examiner. The PROCEDURAL STEPS are arranged in a sequential order. The examiner, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated You will be given a complete procedure to follow unless you have presented a procedure which has been evaluated as complete and workable.

## VII. EVALUATION SCHEME (Total possible score.......25)

DESIGN (15 marks)

| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) |
|---|---|---|
| 1. ____ | 1. ____ | 1. ____ |
| 2. ____ | 2. ____ | 2. ____ |
| 3. ____ | 3. ____ | 3. ____ |
| 4. ____ | 4. ____ | 4. ____ |
| 5. ____ | 5. ____ | 5. ____ |

PERFORMANCE (10 marks)

1. Identity of gas 2
2. Marks are awarded on the basis of the % error in the experimental data.

| Experimental Error | |
|---|---|
| >60% | 0 |
| 40-60% | 2 |
| 20-40% | 4 |
| 10-20% | 5 |
| <10% | 6 |

3. Calculations

| | |
|---|---|
| Step 1 | 1 |
| Step 2 | 1 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

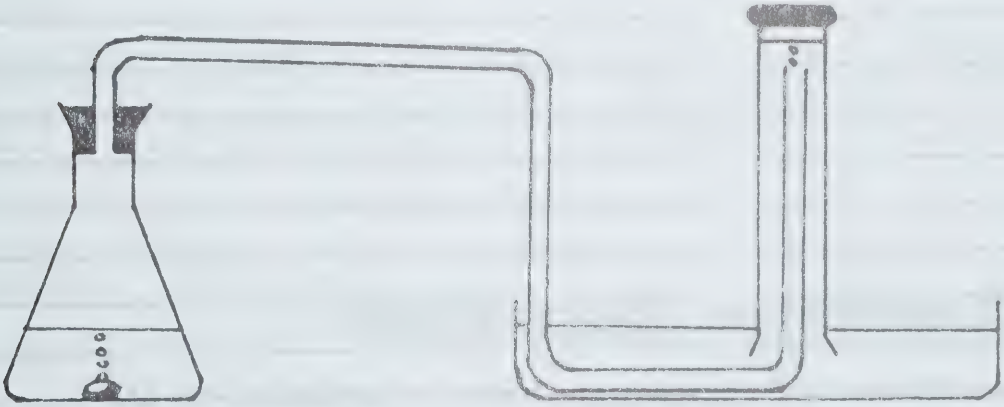
## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

1. Break one tablet into 3 parts. Place each part into a separate test tube.
2. Add water to the test tube.
3. Test the gas in the three test tubes with
    - a) a glowing splint
    - b) a burning splint
    - c) a tube of clear limewater

### PROCEDURAL STEP No. 2

1. Add 50 mL of water to an Erlenmeyer flask.
2. Determine the mass of the Erlenmeyer flask, a one hole rubber stopper and a tablet.
3. Assemble the apparatus as shown in the diagram.



### PROCEDURAL STEP No. 3

1. Remove the rubber stopper, drop the tablet into the water and very quickly replace the stopper in the Erlenmeyer flask.
2. When the reaction is complete (no further effervescence) remove the delivery tube from the one hole stopper and determine the mass of the stopper, flask and its contents. contents.

### PROCEDURAL STEP No. 4

1. The mass and volume of the gas can now be compared.
2. Measure the temperature of the water and atmospheric pressure.
3. Pressure of the gas collected, $p_{gas}$ = Atmospheric pressure, $P_{Atm}$ - Vapour pressure of water, $p_{water}$
4. $p_{gas} = P_{Atm} - p_{watervapour})$

### PROCEDURAL STEP No. 5

1. Convert the volume of the gas at the measured temperature and the partial pressure of the gas ($p_{gas}$) to STP.
2. Calculate the mass of 22.4 L (1 mol) of the gas at STP.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The examiner is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The examiner has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) The tablet used may be any variety that reacts with water to liberate a gas.

(b) Examples of tablets: Alka Seltzer
Dentu Tabs
Calcium carbide

(c) The size of tablet must be chosen to satisfy the size of the available graduated cylinders.

**Procedural Step Model**
**PROBLEM NO. 15**

**Scoring Guide**

Student ______________________

Date ______________________

Score ______________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________________ 6. ______________________
2. ______________________ 7. ______________________
3. ______________________ 8. ______________________
4. ______________________ 9. ______________________
5. ______________________ ______________________

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### For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

### Experimental Design (15 marks)

(Please indicate with a check mark the **procedural steps** designed correctly and the **procedural steps** given to the student)

| Steps Designed Correctly | | Steps Given to the Student |
|---|---|---|
| **Phase I** | **Phase II** | |
| 1. ______ | 1. ______ | 1. ______ |
| 2. ______ | 2 ______ | 2. ______ |
| 3. ______ | 3 ______ | 3. ______ |
| 4. ______ | 4 ______ | 4. ______ |
| 5 ______ | 5 ______ | 5. ______ |

### Performance (10 marks)

(Please enter the appropriate mark in Space III)

| | |
|---|---|
| Identity of gas | 2 |

Marks are awarded on the basis of the % error in the experimental data.

| Experimental Error | |
|---|---|
| >60% | 0 |
| 40-60% | 2 |
| 20-40% | 4 |
| 10-20% | 5 |
| <10% | 6 |

| Calculations | |
|---|---|
| Step 1 | 1 |
| Step 2 | 1 |

### Experimental Design

**Phase I**
No. of steps x 3

○ I

**Phase II**
No. of steps x 2

○ II

**Performance**

○ III

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# Procedural Step Model
# PROBLEM NO. 16

## I. INTRODUCTION

The labels (A,B,C and D) have come off a set of organic compounds. The identity of the compounds is necessary in order for the materials to be used in the laboratory.

## II. SPECIAL LAB KIT

capillary tubes
ice cubes
elastic bands
thermometer ($-10^{\circ}$ - $110^{\circ}$C)
test tubes
mortar and pestle
set of organic compounds (A,B,C and D)

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to identify the set of organic compounds (A,B,C and D). In alphabetical order, the compounds are ______________,

______________, ______________ and ______________.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated You will be given a complete procedure to follow unless you have presented a procedure which has been evaluated as complete and workable.

## VII. EVALUATION SCHEME (Total possible score.......25)

| DESIGN (15 marks) | | | PERFORMANCE (10 marks) | |
|---|---|---|---|---|
| PhaBse I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) | | |
| 1. ____ | 1. ____ | 1. ____ | 4 labels correct | 10 |
| 2. ____ | 2. ____ | 2. ____ | 3 labels correct | 7 |
| 3. ____ | 3. ____ | 3. ____ | 2 labels correct | 5 |
| 4. ____ | 4. ____ | 4. ____ | 1 label correct | 2 |
| 5. ____ | 5. ____ | 5. ____ | 0 labels correct | 0 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

Grind a sample of material A with a mortar and pestle.

### PROCEDURAL STEP No. 2

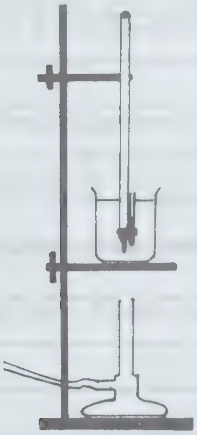
Collect the sample in a capillary tube to a depth of 5 mm.

### PROCEDURAL STEP No. 3

Use an elastic band to attach the capillary tube to the bulb of a thermometer.

### PROCEDURAL STEP No. 4

Set up the apparatus as shown in the diagram.



### PROCEDURAL STEP No. 5

1. Heat the water until the sample melts; observe the temperature at which melting occurs.
2. Repeat the procedure for samples B,C and D.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The teacher is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The teacher has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Select compounds with melting points between 40°C. and 85°C.

(b) Change the coding and samples for different students.

(c) List the compounds both by name and melting point.

(d) The compounds should differ in melting point by at least 5°C.

**Procedural Step Model**
**PROBLEM NO. 16**

**Scoring Guide**

Student ____________________

Date ____________________

Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1 ____________________
2 ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________
7. ____________________
8. ____________________
9. ____________________
____________________

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## For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

**Experimental Design (15 marks)**

(Please indicate with a check mark the **procedural steps** designed correctly and the **procedural steps** given to the student)

| Steps Designed Correctly<br>Phase I | <br>Phase II | Steps Given to the Student |
|---|---|---|
| 1. ______ | 1: ______ | 1 ______ |
| 2. ______ | 2. ______ | 2 ______ |
| 3. ______ | 3. ______ | 3 ______ |
| 4 ______ | 4. ______ | 4 ______ |
| 5 ______ | 5. ______ | 5 ______ |

**Performance (10 marks)**

(Please enter the appropriate mark in Space III)

| | |
|---|---|
| 4 labels correct | 10 |
| 3 labels correct | 7 |
| 2 labels correct | 5 |
| 1 label correct | 2 |
| 0 labels correct | 0 |

**Experimental Design**

Phase I
No. of steps x 3
○ I

Phase II
No. of steps x 2
○ II

Performance
○ III

Total Score ○ I + ○ II + ○ III = ⬡ TOTAL

# Procedural Step Model PROBLEM NO. 17

## I. INTRODUCTION

The labels (A,B,C and D) have come off a set of solid acids, each containing one mole of replaceable hydrogen per mole of compound.

## II. SPECIAL LAB KIT

buret
pipet
pipet bulb
sodium hydroxide solution (0.2 mol/L)
hydrochloric acid solution (0.2 mol/L)
phenolphthalein solution
bromothymol blue solution
litmus paper
unknown acid sample

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to identify the unknown acid. The unknown acid (a monobasic acid - one mole of replaceable hydrogen per mole of compound) is one of ____________, ____________,

______________ or ____________.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated You will be given a complete procedure to follow unless you have presented a procedure which has been evaluated as complete and workable.

## VII. EVALUATION SCHEME (Total possible score.......25)

DESIGN (15 marks)

| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) |
|---|---|---|
| 1. ____ | 1. ____ | 1. ____ |
| 2. ____ | 2. ____ | 2. ____ |
| 3. ____ | 3. ____ | 3. ____ |
| 4. ____ | 4. ____ | 4. ____ |
| 5. ____ | 5. ____ | 5. ____ |

PERFORMANCE (10 marks)

Identity of unknown acid ________ 4

Calculation _ 2

Marks are awarded on the basis of the % error in the Experimental data.

| Experimental Error | |
|---|---|
| >20% ________ | 0 |
| 10-20% ________ | 1 |
| 5-10% ________ | 2 |
| 1-5% ________ | 3 |
| <1% ________ | 4 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

1. Find the mass of a sheet of "weighing paper".
2. Add a quantity (about 1 g) of the unknown acid to the paper and determine the mass of the paper and the unknown acid sample.
3. Add the sample of acid to 25 mL of distilled water in an Erlenmeyer flask.
4. Shake to dissolve the acid.

### PROCEDURAL STEP No. 2

1. Add 3 drops of phenolphthalein solution to the acid solution.
2. Fill a buret with sodium hydroxide solution (0.2 mol/L).

### PROCEDURAL STEP No. 3

1. Add sodium hydroxide solution until the solution just turns pink.
2. Record the volume of sodium hydroxide solution required.

### PROCEDURAL STEP No. 4

Calculate the number of moles of sodium hydroxide consumed.

### PROCEDURAL STEP No. 5

1. No. of moles of acid = No. of moles of sodium hydroxide.
2. Calculate the mass of one mole of the unknown acid.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The teacher is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The teacher has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Select acids that are all monobasic (monoprotic).

(b) Select acids that are soluble in water.

(c) Select acids that differ in molar mass by at least 10%.

(d) In the PROBLEM section (III) list the acids both by name and by formula.

(e) Clue No. 6 - List the acids both by name and by formula.

(f) Some sample acids are:

benzoic acid
citric acid
oleic acid
stearic acid
potassium hydrogen carbonate
potassium hydrogen phthalate
potassium hydrogen tartrate
lauric acid

**Procedural Step Model**
**PROBLEM NO. 17**

**Scoring Guide** PSM.17(5)

Student ______________________
Date ______________________
Score ______________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5 ______________________
6. ______________________
7. ______________________
8. ______________________
9. ______________________
______________________

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### For Teacher's Use Only

### Alternate Solution(s)

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

### Experimental Design (15 marks)

(Please indicate with a check mark the **procedural steps** designed correctly and the **procedural steps** given to the student)

| Steps Designed Correctly | | Steps Given to the Student |
|---|---|---|
| **Phase I** | **Phase II** | |
| 1. ______ | 1. ______ | 1 ______ |
| 2. ______ | 2. ______ | 2. ______ |
| 3. ______ | 3. ______ | 3. ______ |
| 4. ______ | 4. ______ | 4. ______ |
| 5. ______ | 5. ______ | 5. ______ |

### Performance (10 marks)

(Please enter the appropriate mark in Space III)

```
Identity of unknown
acid ________ 4
Calculation__ 2
Marks are awarded on the
basis of the % error in
the Fxperimental data.
Fxperimental Error
>20%__________ 0
10-20%________ 1
5-10%_________ 2
1-5%__________ 3
<1%___________ 4
```

### Experimental Design

**Phase I**
**No. of steps x 3**

○ I

**Phase II**
**No. of steps x 2**

○ II

**Performance**

○ III

---

Total Score ○ I + ○ II + ○ III = ⬡ TOTAL

# Procedural Step Model PROBLEM NO. 18

## I. INTRODUCTION

Pure substances and mixtures can be identified and distinguished by a study of their properties.

## II. SPECIAL LAB KIT

- elastic bands
- capillary tubes
- ice cubes
- test tubes
- set of samples labelled A,B, C and D
- mortar and pestle
- thermometer
- 10 mm test tubes
- scoopulas
- spoons

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to identify the three pure substances and the mixture among the samples labelled A,B,C and D. In alphabetical order, the three pure substances are ____________,

____________ and ____________.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated You will be given a complete procedure to follow unless you have presented a procedure which has been evaluated as complete and workable.

## VII. EVALUATION SCHEME (Total possible score.......25)

DESIGN (15 marks)

| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) |
|---|---|---|
| 1. ____ | 1. ____ | 1. ____ |
| 2. ____ | 2. ____ | 2. ____ |
| 3. ____ | 3. ____ | 3. ____ |
| 4. ____ | 4. ____ | 4. ____ |
| 5. ____ | 5. ____ | 5. ____ |

PERFORMANCE (10 marks)

| | | |
|---|---|---|
| Identity of mixture | ____ | 4 |
| 3 labels correct | ____ | 6 |
| 2 labels correct | ____ | 4 |
| 1 label correct | ____ | 1 |
| 0 labels correct | ____ | 0 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

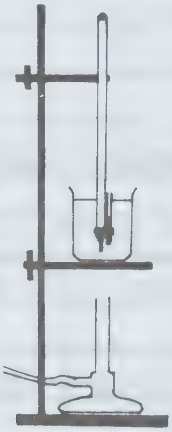
1. Use a mortar and pestle to grind a sample of material A.
2. Collect the sample in a capillary tube to a depth of 5 mm.

### PROCEDURAL STEP No. 2

Use an elastic band to attach the capillary tube to the bulb of a thermometer.

### PROCEDURAL STEP No. 3

Set up the apparatus as shown in the diagram.



### PROCEDURAL STEP No. 4

Heat the water until the sample melts; observe the temperature at which melting occurs.

### PROCEDURAL STEP No. 5

Repeat the procedure for samples B,C and D.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The teacher is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The teacher has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Select three (3) compounds with melting points between 40°C and 85°C.

(b) Change the coding and samples for different students.

(c) For the mixture select a pair of compounds with widely differing melting points. One of the compounds may have a melting point higher than 85°C.

(d) In the PROBLEM section (III) list the compounds both by name and by formula.

(e) Clue No. 5 - List the compounds both by name and formula.

(f) If Handbooks are not available provide the students with lists of compounds and melting points or a comparable set of data.

(g) Suggestions for substances to be used are:

| | |
|---|---|
| Naphthalene | (80°C) |
| Paradichlorobenzene | (53°C) |
| Thymol | (52°C) |
| Lauric Acid | (44°C) |

(h) For the mixture use naphthalene and another low melting solid.

**Procedural Step Model**

**PROBLEM NO. 18**

**Scoring Guide**

Student ______________________

Date ______________________

Score ______________________

**A. Experimental Design**

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

**B. Observations**

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

|  |  |
|---|---|
| 1 ____________ | 6 ____________ |
| 2 ____________ | 7 ____________ |
| 3 ____________ | 8. ____________ |
| 4 ____________ | 9. ____________ |
| 5 ____________ | ____________ |

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### For Teacher's Use Only

### Alternate Solution(s)

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

### Experimental Design (15 marks)

(Please indicate with a check mark the **procedural steps** designed correctly and the **procedural steps** given to the student)

| Steps Designed Correctly |  | Steps Given to the Student |
|---|---|---|
| **Phase I** | **Phase II** |  |
| 1 _____ | 1. _____ | 1 _____ |
| 2 _____ | 2. _____ | 2 _____ |
| 3 _____ | 3. _____ | 3 _____ |
| 4 _____ | 4. _____ | 4 _____ |
| 5 _____ | 5. _____ | 5 _____ |

### Performance (10 marks)

(Please enter the appropriate mark in Space III)

Identity of mixture ____

3 labels correct ____
2 labels correct ____
1 label correct ____
0 labels correct ____

### Experimental Design

| Phase I<br>No. of steps x 3 | Phase II<br>No. of steps x 2 | Performance |
|---|---|---|
| ○ I | ○ II | ○ III |

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# Procedural Step Model
# PROBLEM NO. 19

## I. INTRODUCTION

An alloy is a solid mixture of two or more metals; the composition of the alloy can be determined in a variety of ways.

## II. SPECIAL LAB KIT

Na-Pb alloy sample
gas measuring tube
hydrochloric acid solution (0.2 mol/L)
plastic syringe
oven
overflow can
tweezers
barometer

CAUTION
DO NOT HANDLE THE
ALLOY WITH YOUR HANDS

bromothymol blue solution
filter paper
funnel

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to determine the composition (percent by mass) of the Na-Pb (sodium-lead) alloy. Before completing your design put 5 mL water and/or dilute hydrochloric acid in a small test tube. Add a sample of the alloy to the water/ acid in the test tube.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the examiner. The PROCEDURAL STEPS are arranged in a sequential order. The examiner, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated You will be given a complete procedure to follow unless you have presented a procedure which has been evaluated as complete and workable.

## VII. EVALUATION SCHEME (Total possible score.......25)

| DESIGN (15 marks) | | | PERFORMANCE (10 marks) | |
|---|---|---|---|---|
| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) | Experimental Error | |
| 1. ____ | 1. ____ | 1. ____ | >50% ____ | 0 |
| 2. ____ | 2. ____ | 2. ____ | 40-50% ____ | 2 |
| 3. ____ | 3. ____ | 3. ____ | 30-40% ____ | 4 |
| 4. ____ | 4. ____ | 4. ____ | 20-30% ____ | 5 |
| 5. ____ | 5. ____ | 5. ____ | 10-20% ____ | 7 |
| | | | 5-10% ____ | 9 |
| | | | < 5% ____ | 10 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the examiner.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

1. Find the mass of a piece of "weighing" paper.
2. Select 3 granules of the alloy and determine the total mass of the paper and the alloy.
3. Calculate the mass of the alloy.

### PROCEDURAL STEP No. 2

1. Place the sample of the alloy in a beaker containing 50 mL of distilled water and 3 drops of bromothymol blue solution.
2. Fill a burette with hydrochloric acid solution (0.2 mol/L)
3. Titrate (add dropwise) the hydrochloric acid into the alloy solution until the solution turns green.
4. Record the volume of hydrochloric acid consumed.

### PROCEDURAL STEP No. 3

Calculate the number of moles of hydrochloric acid consumed

No. of moles of HCl = $V_{(L)}$ X Concentration (mol/L)

No. of moles of NaOH = No. of moles of HCl

No. of moles of Na = No. of moles of NaOH

### PROCEDURAL STEP No. 4

Mass of Na in the original sample

= 23 x No. of moles of sodium

### PROCEDURAL STEP No. 5

% (by mass) of sodium in the original sample

$$= \frac{\text{mass of sodium}}{\text{mass of alloy}} \times 100\%$$

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The examiner is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The examiner has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions

(a) Titration
   1) Mass of alloy sample
   2) Reaction of alloy with water
   3) Titration and calculation of % sodium

(b) Gas Collection
   1) Mass of alloy sample
   2) Reaction of alloy with water
   3) Collection of gas and calculation of % sodium

(c) Filtration - this method does not give accurate results
   1) Mass of alloy sample
   2) Reaction of alloy with water
   3) Filtration and mass of lead
   4) Calculation of % sodium

(d) Mass of Sodium Hydroxide
   1) Mass of alloy sample
   2) Reaction of alloy with water
   3) Filtration, evaporation and mass of sodium hydroxide
   4) Calculation of % sodium

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) The alloy is manufactured by J.T. Baker Chemicals - No. 1 - 9413
    The alloy is available from Canlab at approximately $9.00 per lb.
(b) The alloy is approximately 10% sodium, by mass.
(c) Keep the alloy dry until it is being used.
(d) The students must be cautioned not to handle the alloy with their hands. This is an extra precaution - the alloy appears to be easy to handle. The alloy does not react rapidly or vigorously with water. The alloy sinks to the bottom of the beaker and reacts slowly with the water.
(e) As an added safety precaution ALL students MUST be advised to wear Safety Glasses.

# Procedural Step Model PROBLEM NO. 19

**Scoring Guide**

Student ____________

Date ____________

Score ____________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

| | |
|---|---|
| 1 ______ | 6 ______ |
| 2 ______ | 7 ______ |
| 3 ______ | 8 ______ |
| 4 ______ | 9 ______ |
| 5 ______ | ______ |

---

### For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution ☐ 5

**Experimental Design (15 marks)**

(Please indicate with a check mark the **procedural steps** designed correctly and the **procedural steps** given to the student)

| Steps Designed Correctly | | Steps Given to the Student |
|---|---|---|
| **Phase I** | **Phase II** | |
| 1 ______ | 1 ______ | 1 ______ |
| 2 ______ | 2 ______ | 2 ______ |
| 3 ______ | 3 ______ | 3 ______ |
| 4 ______ | 4 ______ | 4 ______ |
| 5 ______ | 5 ______ | 5 ______ |

**Performance (10 marks)**

(Please enter the appropriate mark in Space III)

| Experimental Error | | |
|---|---|---|
| >50% | ______ | 0 |
| 40-50% | ______ | 2 |
| 30-40% | ______ | 4 |
| 20-30% | ______ | 5 |
| 10-20% | ______ | 7 |
| 5-10% | ______ | 9 |
| < 5% | ______ | 10 |

**Experimental Design**

**Phase I**
No. of steps x 3
○ I

**Phase II**
No. of steps x 2
○ II

**Performance**
○ III

---

Total Score ○ I + ○ II + ○ III = ⬡ TOTAL

## I. INTRODUCTION

The medical "cold pack" operates on the principle that various salts absorb heat when they dissolve in water.

## II. SPECIAL LAB KIT

unknown salt sample
thermometer
styrofoam cup
graduated cylinder (100 mL)
balance
paper squares for use on the balance

Data:

The heat absorbed per gram of substance dissolving (heat of solution) in joules per gram:

| | | | |
|---|---|---|---|
| 1) | ammonium chloride | $NH_4Cl$ | 277 J/g |
| 2) | ammonium perchlorate | $NH_4ClO_4$ | 154 J/g |
| 3) | potassium chloride | $KCl$ | 231 J/g |
| 4) | potassium nitrate | $KNO_3$ | 346 J/g |
| 5) | sodium acetate trihydrate | $NaCH_3COO \cdot 3H_2O$ | 145 J/g |

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to identify the unknown salt sample. The unknown is one of the salts listed in the "Data" above.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your designs will be collected and evaluated. You will be given a complete procedure to follow unless you have presented a procedure which has been evaluated as complete and workable.

## VII. EVALUATION SCHEME (Total possible score.......25)

DESIGN (15 marks)

| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) |
|---|---|---|
| 1. ____ | 1. ____ | 1. ____ |
| 2. ____ | 2. ____ | 2. ____ |
| 3. ____ | 3. ____ | 3. ____ |
| 4. ____ | 4. ____ | 4. ____ |
| 5. ____ | 5. ____ | 5. ____ |

PERFORMANCE (10 marks)

Identity of the salt ____ 5

Experimental Error

| | |
|---|---|
| >50% ____ | 0 |
| 30-50% ____ | 2 |
| 10-30% ____ | 4 |
| <10% ____ | 5 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

Find the mass of the sample using the balance.

### PROCEDURAL STEP No. 2

Measure 100 mL of water using the graduated cylinder. Pour the water into the styrofoam cup and measure its temperature.

### PROCEDURAL STEP No. 3

Add the salt to the water in the styrofoam cup and stir until all the salt is dissolved; you may use the thermometer as a stirring rod if you stir very carefully.

### PROCEDURAL STEP No. 4

1. Record the lowest temperature reached by the solution.
2. Calculate the quantity of heat absorbed by the salt-water system.

### PROCEDURAL STEP No. 5

1. Divide the quantity of heat absorbed by the number of grams of salt used.
2. Compare this answer to the values provided under "data". The closest value identifies the unknown salt.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The teacher is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The teacher has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) $KNO_3$ and $NH_4Cl$ give good results; they should be ground in a mortar to get a finer sample. This speeds up dissolving and reduces error.

(b) Provide each student with about 10 g of the salt sample.

(c) Be careful that you do not use hydrated forms of the salts.

(d) The other salts are either hard to obtain or have low solubilities. They are added to the list as distractors.

(e) Problem No. 21 is similar to Problem No. 20, but the data is quoted in kJ/mol in Problem No. 21.

**Procedural Step Model**

**PROBLEM NO. 20**

**Scoring Guide**

Student ____________________

Date ____________________

Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1 ______________________ 6 ______________________
2 ______________________ 7 ______________________
3 ______________________ 8 ______________________
4 ______________________ 9 ______________________
5 ______________________ ______________________

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### For Teacher's Use Only

### Alternate Solution(s)

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution ☐ 5

### Experimental Design (15 marks)

(Please indicate with a check mark the **procedural steps** designed correctly and the **procedural steps** given to the student)

| Steps Designed Correctly | | Steps Given to the Student |
|---|---|---|
| **Phase I** | **Phase II** | |
| 1. ______ | 1. ______ | 1 ______ |
| 2 ______ | 2. ______ | 2. ______ |
| 3 ______ | 3 ______ | 3 ______ |
| 4. ______ | 4. ______ | 4 ______ |
| 5. ______ | 5. ______ | 5 ______ |

### Performance (10 marks)

(Please enter the appropriate mark in Space III)

Identity of the salt ______5

Experimental Error

| | | |
|---|---|---|
| >50% | ______ | 0 |
| 30-50% | ______ | 2 |
| 10-30% | ______ | 4 |
| <10% | ______ | 5 |

### Experimental Design

**Phase I**
**No. of steps x 3**
○ I

**Phase II**
**No. of steps x 2**
○ II

**Performance**
○ III

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

**Procedural Step Model**
**PROBLEM NO. 21**

## I. INTRODUCTION

The medical "cold pack" operates on the principle that various salts absorb heat when they dissolve in water.

## II. SPECIAL LAB KIT

thermometer
styrofoam cup
balance
unknown salt sample
graduated cylinder (100 mL)
paper squares for use on the balance

Data:
The heat absorbed per mole of substance dissolving (heat of solution) in kJ/mole:

| | | | |
|---|---|---|---|
| 1) | ammonium chloride | $NH_4Cl$ | 14.8 kJ/mol |
| 2) | ammonium perchlorate | $NH_4ClO_4$ | 18.0 kJ/mol |
| 3) | potassium chloride | $KCl$ | 17.2 kJ/mol |
| 4) | potassium nitrate | $KNO_3$ | 34.6 kJ/mol |
| 5) | sodium acetate trihydrate | $NaCH_3COO \cdot 3H_2O$ | 19.7 kJ/mol |

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to identify the unknown salt sample. The unknown is one of the salts listed in the "Data" above.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated. You will be given a complete procedure to follow unless you have presented a procedure which has been evaluated as complete and workable.

## VII. EVALUATION SCHEME (Total possible score.......25)

### DESIGN (15 marks)

| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) |
|---|---|---|
| 1. ____ | 1. ____ | 1. ____ |
| 2. ____ | 2. ____ | 2. ____ |
| 3. ____ | 3. ____ | 3. ____ |
| 4. ____ | 4. ____ | 4. ____ |
| 5. ____ | 5. ____ | 5. ____ |

### PERFORMANCE (10 marks)

| | |
|---|---|
| Identity of the salt ____ | 4 |
| Calculation of the molar masses | 2 |
| Experimental Error | |
| >50% ____ | 0 |
| 30-50% ____ | 2 |
| 10-30% ____ | 4 |
| <10% ____ | 5 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

Find the mass of the sample using the balance.

### PROCEDURAL STEP No. 2

Measure 100 mL of water using the graduated cylinder. Pour the water into the styrofoam cup and measure its temperature.

### PROCEDURAL STEP No. 3

Add the salt to the water in the styrofoam cup and stir until all the salt is dissolved; you may use the thermometer as the stirring rod if you stir very carefully.

### PROCEDURAL STEP No. 4

1. Record the lowest temperature reached by the solution.
2. Calculate the quantity of heat absorbed by the salt-water system.

### PROCEDURAL STEP No. 5

1. Calculate the quantity of heat absorbed in kJ/mol.
2. Compare this answer to the values provided under "data". The closest value identifies the unknown salt.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The teacher is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The teacher has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) $KNO_3$ and $NH_4Cl$ give good results; they should be ground in a mortar to get a finer sample. This speed up dissolving and reduces error.

(b) Provide each student with about 10 g of the salt sample.

(c) Be careful that you do not use hydrated forms of the salts.

(d) The other salts are either hard to obtain or have low solubilities. They are added to the list as distractors.

(e) Problem No. 21 is similar to Problem No. 20, but data is quoted in J/g in Problem No. 20.

**Procedural Step Model**

**PROBLEM NO. 21**

**Scoring Guide**

Student ______________________

Date ______________________

Score ______________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
6. ______________________
7. ______________________
8. ______________________
9. ______________________
______________________

---

## For Teacher's Use Only

### Alternate Solution(s)

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

### Experimental Design (15 marks)

(Please indicate with a check mark the **procedural steps** designed correctly and the **procedural steps** given to the student)

| Steps Designed Correctly | | Steps Given to the Student |
|---|---|---|
| Phase I | Phase II | |
| 1 ______ | 1 ______ | 1. ______ |
| 2 ______ | 2 ______ | 2. ______ |
| 3 ______ | 3 ______ | 3 ______ |
| 4 ______ | 4 ______ | 4. ______ |
| 5 ______ | 5 ______ | 5. ______ |

### Performance (10 marks)

(Please enter the appropriate mark in Space III)

Identity of the salt ______ 4

Calculation of the molar masses ______ 2

Experimental Frror

>50% ______ 0
30-50% ______ 2
10-30% ______ 4
<10% ______ 5

### Experimental Design

**Phase I**
No. of steps x 3
○ I

**Phase II**
No. of steps x 2
○ II

**Performance**
○ III

---

Total Score ○ I + ○ II + ○ III = ⬡ TOTAL

# Procedural Step Model PROBLEM NO. 22

## I. INTRODUCTION

The density of a gas can be used to identify the gas; density is a characteristic property of all materials.

## II. SPECIAL LAB KIT

alka seltzer tablet
flask
delivery tube
graduated cylinder
splints
syringe (50 mL)
nichrome or copper wire loops
saturated barium hydroxide solution
saturated calcium hydroxide solution

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to determine the density of the gas produced when an Alka Seltzer tablet is added to water.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated. You will be given a complete procedure to follow unless you have presented a procedure which has been evaluated as complete and workable.

## VII. EVALUATION SCHEME (Total possible score.......25)

DESIGN (15 marks)

| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) |
|---|---|---|
| 1. ____ | 1. ____ | 1. ____ |
| 2. ____ | 2. ____ | 2. ____ |
| 3. ____ | 3. ____ | 3. ____ |
| 4. ____ | 4. ____ | 4. ____ |
| 5. ____ | 5. ____ | 5. ____ |

PERFORMANCE (10 marks)

Identity of gas____3
Choice of units____1

Experimental Error

| | |
|---|---|
| >40%____ | 0 |
| 30-40%____ | 1 |
| 20-30%____ | 2 |
| 10-20%____ | 3 |
| 5-10%____ | 4 |
| < 5%____ | 6 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

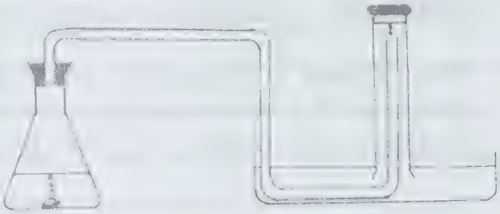
## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

1. Break an Alka Seltzer tablet into pieces.
2. Place chips of the tablet in water and test the effervescent gas with a glowing splint and a burning splint. Test the gas with drops or films of saturated barium hydroxide and/or calcium hydroxide solutions.

### PROCEDURAL STEP No. 2

1. Place 50 mL of water in a flask.
2. Determine the mass of the stoppered flask and a piece of the Alka Seltzer tablet; stopper the flask.
3. Set up the aparatus as shown in the diagram. Remove the stopper, add the piece of Alka Seltzer tablet and quickly restopper the flask.



### PROCEDURAL STEP No. 3

1. When the reaction ceases measure the volume of gas collected, the temperature of the water and then remove the delivery tube from the reaction flask.
2. Determine the mass of the reaction flask.

### PROCEDURAL STEP No. 4

Calculate the mass of the gas collected.

### PROCEDURAL STEP No. 5

Calculate the density of the gas collected.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The teacher is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The teacher has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Prepare copper or nichrome wire loops that can be used for the $CO_2(g)$ test.

(b) The loop when dipped in $Ba(OH)_2(aq)$ or in $Ca(OH)_2(aq)$ will produce a film of the solution. The film when placed in contact with bubbles of $CO_2(g)$ will turn milky very quickly.

(c) Prepare graduated cylinders which are large enough to accommodate the gas from half an Alka Seltzer tablet.

(d) Try antacids other than Alka Seltzer.

Some examples are

(i) Bromoseltzer

(ii) Bicarbonate of soda

# Procedural Step Model
# PROBLEM NO. 22

**Scoring Guide** PSM.22(5)

Student ____________________

Date ____________________

Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________________ 6. ______________________
2. ______________________ 7. ______________________
3. ______________________ 8. ______________________
4. ______________________ 9. ______________________
5. ______________________ ______________________

---

### For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution. ☐ 5

**Experimental Design (15 marks)**

(Please indicate with a check mark the **procedural steps** designed correctly and the **procedural steps** given to the student)

| Steps Designed Correctly | | Steps Given to the Student |
|---|---|---|
| **Phase I** | **Phase II** | |
| 1. ______ | 1. ______ | 1. ______ |
| 2. ______ | 2. ______ | 2. ______ |
| 3. ______ | 3. ______ | 3. ______ |
| 4 ______ | 4. ______ | 4. ______ |
| 5 ______ | 5. ______ | 5. ______ |

**Performance (10 marks)**

(Please enter the appropriate mark in Space III)

Identity of gas______3
Choice of units______1

Experimental Error

>40%______0
30-40%______1
20-30%______2
10-20%______3
5-10%______4
< 5%______6

**Experimental Design**

**Phase I**
No. of steps x 3
○ I

**Phase II**
No. of steps x 2
○ II

**Performance**
○ III

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# Procedural Step Model
# PROBLEM NO. 23

## I. INTRODUCTION

Product X neutralizes 36 times its own "weight" in excess stomach juices. There are many antacids on the market. Some are more effective than others.

## II. SPECIAL LAB KIT

buret
pipet
eye dropper
graduated cylinder

sodium hydroxide solution (0.2 mol/L)
hydrochloric acid solution (0.2 mol/L)
phenolphthalein solution
bromothymol blue solution
tablets of 2 or 3 different antacids

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to determine which of the 2 antacid tablets in your kit is the "best" antacid. Express your answer in moles of acid consumed per tablet.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated. You will be given a complete procedure to follow unless you presented a procedure which has been evaluated as complete and workable.

## VII. EVALUATION SCHEME (Total possible score.......25)

DESIGN (15 marks)

| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) |
|---|---|---|
| 1. ____ | 1. ____ | 1. ____ |
| 2. ____ | 2. ____ | 2. ____ |
| 3. ____ | 3. ____ | 3. ____ |
| 4. ____ | 4. ____ | 4. ____ |
| 5. ____ | 5. ____ | 5. ____ |

PERFORMANCE (10 marks)

Best Antacid____2
Calculations____2
Experimental Error
Tablet 1
>20%____0
5-20%____1
< 5%____2
Tablet 2
>10%____0
5-10%____1
< 5%____2
Tablet 3
> 5%____0
1-5%____1
< 1%____2

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

1. Determine the mass of tablet 1.
2. Dissolve tablet 1 in 50 mL of water in an Erlenmeyer flask.

### PROCEDURAL STEP No. 2

1. Add 3 drops of phenolphthalein solution to the antacid solution.
2. Fill a buret with the hydrochloric acid solution.

### PROCEDURAL STEP No. 3

Add the hydrochloric acid solution to the antacid until the solution turns colourless.

### PROCEDURAL STEP No. 4

Calculate the quantity (no. of mol) of hydrochloric acid required to neutralize the antacid.

### PROCEDURAL STEP No. 5

1. Repeat the procedure(s) with tablets 2 and 3.
2. Calculate the quantity of acid neutralized per unit mass (gram) of each of the tablets.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The teacher is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The teacher has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) A variety of antacids are available for study.

(b) Provide students with different antacids - coded appropriately.

(c) In the commercial - "36 times its weight in excess stomach acidity" refers to the "weight" of the acid solution (including the aqueous component of the solution).

(d) Some commercial antacids that can be used are:

- (i) Alka Seltzer
- (ii) Maalox
- (iii) Tums
- (iv) Rolaids

**Procedural Step Model**
**PROBLEM NO. 23**

**Scoring Guide** PSM.23(5)

Student ____________________

Date ____________________

Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
6 ______________________
7 ______________________
8 ______________________
9. ______________________
______________________

---

## For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution ☐ 5

**Experimental Design (15 marks)**

(Please indicate with a check mark the **procedural steps** designed correctly and the **procedural steps** given to the student)

| Steps Designed Correctly | | Steps Given to the Student |
|---|---|---|
| **Phase I** | **Phase II** | |
| 1 ______ | 1. ______ | 1. ______ |
| 2 ______ | 2. ______ | 2. ______ |
| 3 ______ | 3. ______ | 3. ______ |
| 4 ______ | 4 ______ | 4. ______ |
| 5 ______ | 5. ______ | 5. ______ |

**Performance (10 marks)**

(Please enter the appropriate mark in Space III)

Best Antacid ____ 2
Calculations ____ 2
Experimental Error
Tablet 1
>20% ____ 0
5-20% ____ 1
< 5% ____ 2
Tablet 2
>10% ____ 0
5-10% ____ 1
< 5% ____ 2
Tablet 3
> 5% ____ 0
1-5% ____ 1
< 1% ____ 2

**Experimental Design**

**Phase I**
**No. of steps x 3**
○ I

**Phase II**
**No. of steps x 2**
○ II

**Performance**
○ III

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# Procedural Step Model PROBLEM NO. 24

## I. INTRODUCTION

Mass determinations and calculations can be performed without the use of a balance.

## II. SPECIAL LAB KIT

magnesium ribbon (prepared sample)
graduate cylinder (100 mL, 250 mL)
hydrochloric acid solution (6 mol/L)
glass tray
copper wire
thermometer
barometer
syringe (50 mL)
emery paper

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to determine the mass of the sample of magnesium ribbon provided to you. *YOU MAY NOT USE A BALANCE*

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated. You will be given a complete procedure to follow unless you presented a procedure which has been evaluated as complete and workable.

## VII. EVALUATION SCHEME (Total possible score......25)

DESIGN (15 marks)

| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) |
|---|---|---|
| 1. ____ | 1. ____ | 1. ____ |
| 2. ____ | 2. ____ | 2. ____ |
| 3. ____ | 3. ____ | 3. ____ |
| 4. ____ | 4. ____ | 4. ____ |
| 5. ____ | 5. ____ | 5. ____ |

PERFORMANCE (10 marks)

Calculations____2

Experimental Error

| | |
|---|---|
| >35%____ | 0 |
| 20-35%____ | 2 |
| 10-20%____ | 3 |
| 5-10%____ | 4 |
| < 5%____ | 6 |

NOTE

(1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

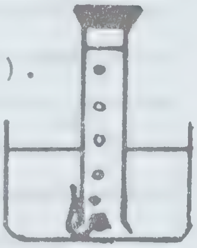
## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

1. Select a sample of magnesium ribbon and fold it into a small rectangular package.

2. Wrap the magnesium package with a length of copper wire.

### PROCEDURAL STEP No. 2



1. Fill a gas measuring tube (or graduated cylinder) to a depth of 10 cm with hydrochloric acid solution (6 mol/L).

2. Carefully fill the gas measuring tube (to overflowing) with water.

3. Cover the gas measuring tube with a square of paper. Invert the tube into a tray of water.

4. Set up the apparatus as shown in the diagram.

### PROCEDURAL STEP No. 3

1. Measure and record the volume of gas collected.

2. Measure and record the temperature of the water.

3. Measure and record the atmospheric pressure.

### PROCEDURAL STEP No. 4

Calculate the partial pressure of hydrogen ($p_{H_2}$)

$$p_{H_2} = P_{Atm} - p_{H_2O}$$

### PROCEDURAL STEP No. 5

$Mg(s) + 2HCl(aq) \rightarrow MgCl(aq) + H_2(g)$

Calculate the mass of magnesium consumed.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The teacher is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The teacher has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Determine the mass of a 1 m length of Mg ribbon; provide the students with the mass/metre of Mg ribbon.

(b) Select lengths of Mg ribbon which will produce the volume of hydrogen, $H_2$, that fits the volume of the gas collection container.

(c) Lengths of glass tubing can be converted to gas measuring tubes by gluing a scale onto the tube and stoppering one end of the tube.

**Procedural Step Model**
**PROBLEM NO. 24**

**Scoring Guide** PSM.24(5)

Student ______________________

Date ______________________

Score ______________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1 ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
6 ______________________
7 ______________________
8 ______________________
9 ______________________
______________________

---

## For Teacher's Use Only

### Alternate Solution(s)

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution. ☐ 5

### Experimental Design (15 marks)

(Please indicate with a check mark the **procedural steps** designed correctly and the **procedural steps** given to the student)

**Steps Designed Correctly** - **Steps Given to the Student**

| Phase I | Phase II | |
|---|---|---|
| 1. ______ | 1. ______ | 1. ______ |
| 2. ______ | 2. ______ | 2. ______ |
| 3. ______ | 3. ______ | 3. ______ |
| 4. ______ | 4. ______ | 4. ______ |
| 5. ______ | 5. ______ | 5. ______ |

### Performance (10 marks)

(Please enter the appropriate mark in Space III)

Calculations ____ 2

Experimental Error

| | | |
|---|---|---|
| >35% | ____ | 0 |
| 20-35% | ____ | 2 |
| 10-20% | ____ | 3 |
| 5-10% | ____ | 4 |
| < 5% | ____ | 6 |

### Experimental Design

**Phase I**
**No. of steps x 3**
○ I

**Phase II**
**No. of steps x 2**
○ II

**Performance**
○ III

---

Total Score ○ I + ○ II + ○ III = ⬡ TOTAL

# Procedural Step Model
# PROBLEM NO. 25

## I. INTRODUCTION

So far in your study of chemistry you have looked at and worked with many different substances. You must have observed that many substances dissolve in water and that some of these soluble substances produce coloured solutions.

## II. SPECIAL LAB KIT

beakers
eye droppers
light source
pipets
flasks
Cobalt(II) chloride hexahydrate
graduated cylinders
test tubes (uniform size)
balances (centigram)
2 unknown solutions (labelled A and B) whose concentrations are less than 1.0 mol/L

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to determine the the concentrations of two solutions of cobalt chloride of unknown concentration.

DATA:

(a) The solubility of cobalt(II) chloride is approximately 50 g per 100 g of water at room temperature.
(b) The mass of 1 mol of cobalt(II) chloride hexahydrate is 237 g. 100 mL of a solution (1 mol/L) contains 23.7 g of cobalt(II) chloride hexahydrate.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated. You will be given a complete procedure to follow unless you presented a procedure which has been evaluated as complete and workable.

## VII. EVALUATION SCHEME (Total possible score.......25)

DESIGN (15 marks)

| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) |
|---|---|---|
| 1. ____ | 1. ____ | 1. ____ |
| 2. ____ | 2. ____ | 2. ____ |
| 3. ____ | 3. ____ | 3. ____ |
| 4. ____ | 4. ____ | 4. ____ |
| 5. ____ | 5. ____ | 5. ____ |

PERFORMANCE (10 marks)

Solution A

Experimental Error

| | |
|---|---|
| >50% ____ | 0 |
| 35-50% ____ | 2 |
| 20-35% ____ | 3 |
| <20% ____ | 5 |

Solution B

Experimental Error

| | |
|---|---|
| >40% ____ | 0 |
| 20-30% ____ | 3 |
| <20% ____ | 5 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

Dissolve 23.7 g of cobalt(II) chloride hexahydrate in sufficient water to make 100 mL of solution.

### PROCEDURAL STEP No. 2

Prepare a series of cobalt(II) chloride solutions by dilution with water.

a) 50 mL of standard solution (1.0 mol/L) to 100 mL.
b) 25 mL of standard solution (1.0 mol/L) to 100 mL.
c) 10 mL of standard solution (1.0 mol/L) to 100 mL.
d) 5 mL of standard solution (1.0 mol/L) to 100 mL.

### PROCEDURAL STEP No. 3

Observe the colour intensities of the solutions by viewing them through the vertical depth of liquid.

### PROCEDURAL STEP No. 4

Match the colour viewed through the unknown solution(s) with one of the known solutions.

### PROCEDURAL STEP No. 5

Calculate the concentration of the unknown solution(s).

$$\text{Concentration}_{\text{UNKNOWN}} = \frac{\text{Depth}_{\text{STANDARD}}}{\text{Depth}_{\text{UNKNOWN}}} \times \text{Concentration}_{\text{STANDARD}}$$

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The teacher is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The teacher has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) An overhead projector can be used as a light box. Place a sheet of paper over the stage of the projector in order to produce a source of diffuse white light.

(b) Substitute a variety of coloured salts for cobalt chloride.

(c) The concentrations of the unknowns should be accepted within wide limits (20%).

(d) This problem is a variation on the $KSCN/Fe(NO_3)_3$ equilibrium experiment.

**Procedural Step Model**

**PROBLEM NO. 25**

**Scoring Guide** PSM.25(5)

Student ____________________

Date ____________________

Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1 ____________________
2. ____________________
3 ____________________
4 ____________________
5. ____________________
6. ____________________
7. ____________________
8. ____________________
9. ____________________
____________________

---

## For Teacher's Use Only

**Alternate Solution(s)**
Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

**Experimental Design (15 marks)**
(Please indicate with a check mark the **procedural steps** designed correctly and the **procedural steps** given to the student)

| Steps Designed Correctly | | Steps Given to the Student |
|---|---|---|
| **Phase I** | **Phase II** | |
| 1 ____ | 1 ____ | 1. ____ |
| 2 ____ | 2 ____ | 2. ____ |
| 3. ____ | 3. ____ | 3 ____ |
| 4. ____ | 4. ____ | 4. ____ |
| 5. ____ | 5. ____ | 5. ____ |

**Performance (10 marks)**
(Please enter the appropriate mark in Space III)

Solution A

| Experimental | Error |
|---|---|
| >50% ____ | 0 |
| 35-50% ____ | 2 |
| 20-35% ____ | 3 |
| <20% ____ | 5 |

Solution B

| Experimental | Error |
|---|---|
| >40% ____ | 0 |
| 20-30% ____ | 3 |
| <20% ____ | 5 |

**Experimental Design**

**Phase I**
**No. of steps x 3**
○ I

**Phase II**
**No. of steps x 2**
○ II

**Performance**
○ III

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

## Procedural Step Model PROBLEM NO. 26

## I. INTRODUCTION

So far in your study of chemistry you have looked at and worked with many different substances. You must have observed that many substances dissolve in water and that some of these soluble substances produce coloured solutions. In this problem you will investigate coloured solutions.

## II. SPECIAL LAB KIT

beakers
eye droppers
light sources
pipets
flasks
cobalt(II) chloride hexahydrate
test tubes (uniform size)
balances (centigram)
2 unknown solutions (labelled A and B)
graduated cylinders

DATA:
(a) The solubility of cobalt(II) chloride is approximately 50 g per 100 g of water at room temperature.
(b) The solution is coloured.
(c) The mass of 1 mol of cobalt(II) chloride hexahydrate is 237 g. 100 mL of a solution (1 mol/L) contains 23.7 g of cobalt(II) chloride hexahydrate.

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to:
(a) determine if there is any relationship between the concentration of a solution and the amount (or intensity) of the colour that the solution exhibits,
(b) determine the nature of the relationship if one exists, and
(c) determine the concentration of two solutions of cobalt chloride of unknown concentration.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.
NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated. You will be given a complete procedure to follow unless you presented a procedure which has been evaluated as complete and workable.

## VII. EVALUATION SCHEME (Total possible score.......25)

### DESIGN (15 marks)

| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) |
|---|---|---|
| 1. ____ | 1. ____ | 1. ____ |
| 2. ____ | 2. ____ | 2. ____ |
| 3. ____ | 3. ____ | 3. ____ |
| 4. ____ | 4. ____ | 4. ____ |
| 5. ____ | 5. ____ | 5. ____ |

### PERFORMANCE (10 marks)

a) Is there a relationship? ____1

b) Nature of relationship? ____2

c) Solution A Experimental Error

| | |
|---|---|
| >50% | ____0 |
| 35-50% | ____2 |
| 20-35% | ____3 |
| <20% | ____4 |

d) Solution B Experimental Error

| | |
|---|---|
| >40% | ____0 |
| 20-40% | ____1 |
| <20% | ____3 |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

Dissolve 23.7 g of cobalt(II) chloride hexahydrate in sufficient water to make 100 mL of solution.

### PROCEDURAL STEP No. 2

Prepare a series of cobalt(II) chloride solutions by dilution with water.

a) 50 mL of standard solution (1.0 mol/L) to 100 mL.
b) 25 mL of standard solution (1.0 mol/L) to 100 mL.
c) 10 mL of standard solution (1.0 mol/L) to 100 mL.
d) 5 mL of standard solution (1.0 mol/L) to 100 mL.

### PROCEDURAL STEP No. 3

Observe the colour intensities of the solutions by viewing them through the vertical depth of liquid.

### PROCEDURAL STEP No. 4

Match the colour viewed through the unknown solution(s) with one of the known solutions.

### PROCEDURAL STEP No. 5

Calculate the concentration of the unknown solution(s).

$$\text{Concentration}_{\text{UNKNOWN}} = \frac{\text{Depth}_{\text{STANDARD}}}{\text{Depth}_{\text{UNKNOWN}}} \times \text{Concentration}_{\text{STANDARD}}$$

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The teacher is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The teacher has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) An overhead projector can be used as a light box. Place a sheet of paper over the stage of the projector in order to produce a source of diffuse white light.

(b) Substitute a variety of coloured salts for cobalt chloride.

(c) The concentrations of the unknowns should be accepted within wide limits (20%).

(d) This problem is a variation on the $KSCN/Fe(NO_3)_3$ equilibrium experiment.

**Procedural Step Model**
**PROBLEM NO. 26**

**Scoring Guide** PSM.26(5)

Student ______________________

Date ______________________

Score ______________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1 ______________________ 6 ______________________
2 ______________________ 7 ______________________
3 ______________________ 8. ______________________
4. ______________________ 9. ______________________
5 ______________________ ______________________

---

## For Teacher's Use Only

### Alternate Solution(s)

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

### Experimental Design (15 marks)

(Please indicate with a check mark the **procedural steps** designed correctly and the **procedural steps** given to the student)

| Steps Designed Correctly<br>Phase I | Steps Designed Correctly<br>Phase II | Steps Given to the Student |
|---|---|---|
| 1 _____ | 1 _____ | 1 _____ |
| 2 _____ | 2. _____ | 2 _____ |
| 3 _____ | 3 _____ | 3 _____ |
| 4 _____ | 4 _____ | 4 _____ |
| 5 _____ | 5 _____ | 5 _____ |

### Performance (10 marks)

(Please enter the appropriate mark in Space III)

a) Is there a relationship? _____1
b) Nature of relationship? _____2
c) Solution A
Experimental Error
>50% _____0
35-50% _____2
20-35% _____3
<20% _____4
d) Solution B
Experimental Error
>40% _____0
20-40% _____1
<20% _____3

### Experimental Design

**Phase I**
**No. of steps x 3**
○ I

**Phase II**
**No. of steps x 2**
○ II

**Performance**
○ III

---

Total Score ○ I + ○ II + ○ III = ⬡ TOTAL

# Procedural Step Model PROBLEM NO. 27

## I. INTRODUCTION

The labels (A,B,C and D) have come off a set of solid organic acids. The identity of the acids is necessary in order for the materials to be used in the laboratory.

## II. SPECIAL LAB KIT

buret
pipet
pipet bulb
sodium hydroxide solution (0.2 mol/L)
hydrochloric acid solution (0.2 mol/L)
phenolphthalein solution
bromothymol blue solution
litmus paper
set of organic acids (A,B,C and D)

## III. PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to identify the set of organic acids (A,B,C and D). In alphabetical order, the acids are ______________,

______________, ______________ and ______________.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated. You will be given a complete procedure to follow unless you have presented a procedure which has been evaluated as complete and workable.

## VII. EVALUATION SCHEME (Total possible score.......25)

| DESIGN (15 marks) | | | PERFORMANCE (10 marks) |
|---|---|---|---|
| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) | |
| 1. ____ | 1. ____ | 1. ____ | 1 label correct____ 0 |
| 2. ____ | 2. ____ | 2. ____ | 2 labels correct____ 5 |
| 3. ____ | 3. ____ | 3. ____ | 3 labels correct____ 7 |
| 4. ____ | 4. ____ | 4. ____ | 4 labels correct____10 |
| 5. ____ | 5. ____ | 5. ____ | |

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

1. Find the mass the of a sheet of "weighing paper".
2. Add a quantity of sample A to the paper (about 1 g) and determine the mass of the paper and sample A.
3. Add the sample to 25 mL of distilled water in an Erlenmeyer flask.
4. Shake to dissolve the acid.

### PROCEDURAL STEP No. 2

1. Add 3 drops of phenolphthalein solution to the acid solution.
2. Fill a buret with sodium hydroxide solution (0.2 mol/L).

### PROCEDURAL STEP No. 3

1. Add sodium hydroxide solution until the solution just turns pink.
2. Record the volume of sodium hydroxide solution required.

### PROCEDURAL STEP No. 4

Calculate the number of moles of sodium hydroxide consumed.

### PROCEDURAL STEP No. 5

1. No. of moles of acid = No. of moles of sodium hydroxide.
2. Calculate the mass of one mole of acid A.
3. Repeat with acids B,C and D.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The teacher is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The teacher has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions

(a)

(b)

(c)

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(a) Select acids that are all monobasic (monoprotic).

(b) Select acids that are soluble in water.

(c) Select acids that differ in molar mass by at least 10%.

(d) In the PROBLEM section (III) list the compounds both by name and by formula.

(e) PROCEDURAL STEP No. 5 - List the compounds both by name and by formula.

(f) Some sample acids are:

benzoic acid
citric acid
oleic acid
stearic acid

potassium hydrogen carbonate
potassium hydrogen phthalate
potassium hydrogen tartrate
lauric acid

**Procedural Step Model**
**PROBLEM NO. 27**

**Scoring Guide** PSM.27(5)

Student ______________________

Date ______________________

Score ______________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1 ______
2. ______
3 ______
4 ______
5 ______
6. ______
7. ______
8. ______
9. ______
______

---

## For Teacher's Use Only

### Alternate Solution(s)

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution. ☐ 5

### Experimental Design (15 marks)

(Please indicate with a check mark the **procedural steps** designed correctly and the **procedural steps** given to the student)

| Steps Designed Correctly | | Steps Given to the Student |
|---|---|---|
| **Phase I** | **Phase II** | |
| 1 ______ | 1. ______ | 1. ______ |
| 2. ______ | 2. ______ | 2. ______ |
| 3. ______ | 3. ______ | 3. ______ |
| 4 ______ | 4. ______ | 4. ______ |
| 5. ______ | 5. ______ | 5. ______ |

### Performance (10 marks)

(Please enter the appropriate mark in Space III)

1 label correct ____0
2 labels correct____5
3 labels correct____7
4 labels correct___10

### Experimental Design

**Phase I**
**No. of steps x 3**
○ I

**Phase II**
**No. of steps x 2**
○ II

**Performance**
○ III

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL

# Procedural Step Model PROBLEM NO. 28

## I. INTRODUCTION

The chemist is frequently called upon to identify an unknown metal. On some of these occasions the materials and equipment available for use are limited. All of the initial observations indicate that the unknown metal is divalent.

## II. SPECIAL LAB KIT

100 mL graduated cylinder
hydrochloric acid (2 mol/L)
gelatin capsule containing powdered metal
thermometer
sodium hydroxide solution (0.5 mol/L)
pipet
buret
phenolphthaolein solution
bromothymol blue solution
A barometer will be available in the laboratory.

## III. PROBLEM

You are provided with a capsule containing a sample of a powdered metal. The metal is one of a)______________,

b)______________ , c)______________ , d)______________.

Using only the materials in the "SPECIAL LAB KIT" design an experiment to determine the identity of the metal.

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do Not proceed with the actual experimental work until the teacher has checked and approved the experimental design that you have suggested.

NOTE - You are also provided with a kit of standard laboratory glassware and hardware.

## IV. ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

## V. TIMING

(1) Time allowed for the complete problem 40 min

(2) Time allowed for the Experimental Design 15 min

## VI. TEST FORMAT

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

You are advised to ask for PROCEDURAL STEPS as soon as you think that you are "stuck". There is ample opportunity provided to recover Design marks.

After 15 min your design will be collected and evaluated. You will be given a complete procedure to follow unless you have presented a procedure which has been evaluated as complete and workable.

## VII. EVALUATION SCHEME (Total possible score.......25)

### DESIGN (15 marks)

| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) |
|---|---|---|
| 1. ____ | 1. ____ | 1. ____ |
| 2. ____ | 2. ____ | 2. ____ |
| 3. ____ | 3. ____ | 3. ____ |
| 4. ____ | 4. ____ | 4. ____ |
| 5. ____ | 5. ____ | 5. ____ |

### PERFORMANCE (10 marks)

1. Marks are awarded on the basis of the % error in the experimental data.

Experimental Error

| | |
|---|---|
| >30% | 0 |
| 20-30% | 2 |
| 10-20% | 3 |
| <10% | 4 |

2. Calculations
   - a) Step 1______1
   - b) Step 2______1
   - c) Step 3______1
3. Identification of the metal. 3

NOTE (1) You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any other materials provided by your teacher.

(2) You must leave ALL your "rough work" with the teacher.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII. PROCEDURAL STEPS

### PROCEDURAL STEP No. 1

(1) Use the graduated cylinder to measure 100 mL of the hydrochloric acid (HCl) solution.
(2) Pour the HCl into a 600 mL beaker.

### PROCEDURAL STEP No. 2

(1) Determine the mass of the capsule and the metal.
(2) Empty the contents of the capsule into the HCl solution.
(3) Determine the mass of the empty capsule.
(4) Calculate the mass of metal used.
(5) Allow the reaction to proceed to completion.

### PROCEDURAL STEP No. 3

(1) Add three drops of bromothymol blue solution to the reaction vessel.
(2) Fill a buret with the sodium hydroxide solution.
(3) Titrate the excess acid with sodium hydroxide solution until the indicator colour is neutral.
(4) Record the volume of sodium hydroxide solution.

### PROCEDURAL STEP No. 4

(1) $M(s) + 2HCl(aq) \rightarrow MCl_2(aq) + H_2(g)$
(2) $M(s) + 2H^+(aq) \rightarrow M^{2+}(aq) + H_2(g)$
(3) Volume of sodium hydroxide, NaOH, consumed = ______ mL
(4) No. of moles of NaOH consumed $= \text{vol(L)} \times \text{Concentration (mol/L)}$ $= y$ mol
(5) No. of moles of HCl in 100 mL of solution $= \frac{100 \times 2.0}{1000}$ mol $= 0.20$ mol
(6) No. of moles of HCl consumed $= (0.20 - y)$ mol
(7) No. of moles of metal in the sample $= \frac{0.20 - y}{2}$ mol

### PROCEDURAL STEP No. 5

(1) Relative Atomic Mass of the metal

$$= \frac{\text{Mass of Metal}}{\text{No. of mol of metal}}$$

(2) The metal can now be identified by comparing the calculated Relative Atomic Mass of the metal with the published values for the metals listed in section III.

## IX. SUGGESTED PROCEDURES

There are many procedures for solving each of the problems. The set of five PROCEDURAL STEPS outlines only one of the many possible procedures that might be designed by the students.

The teacher is responsible for approving and supplying the materials for any different procedure(s) that might be suggested. The teacher has the option to allow marks under the category of Additional Solution(s) for procedures other than "The Suggested Procedure".

Additional Suggestions
(a) React the metal with acid and evaporate to dryness.
(b) React the metal with acid and collect the hydrogen gas.
(c) React the metal with oxygen and determine the mass of the oxide.
(d) React the metal with oxygen and determine the mass of the chloride.
(e) React the metal with steam and determine the mass of the oxide.

## X. SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for each of the problems.

(1) The metals that may be used are:

| | | | | | |
|---|---|---|---|---|---|
| Magnesium | (Mg) | 24.2 | Nickel | (Ni) | 58.7 |
| Calcium | (Ca) | 40.1 | Zinc | (Zn) | 65.4 |
| Chromium | (Cr) | 52.0 | Cadmium | (Cd) | 112.4 |
| Iron | (Fe) | 55.9 | Tin | (Sn) | 118.7 |

$$M(s) + 2H^+(aq) \rightarrow M^{2+}(aq) + H_2(g)$$

(2) Provide the students with sufficient metal to consume about 75% of the acid.
(3) Provide the students with "correct" concentrations of the hydrochloric acid and sodium hydroxide solutions.
(4) In section III indicate to the student four (4) of the metals listed (one of them to be the correct answer).
(5) Select four metals with significantly different atomic weights so that the student can readily get the correct answer.
e.g. (a) Mg, Ca, Cd, Zn (b) Ca, Mg, Fe, Sn (c) Zn, Cr, Sn, Mg
(6) Check that the metal(s) you have selected do react completely with the acid. You may have to increase the acid concentration.
(7) Provide a variety of sizes of beakers and graduated cylinders for the students to select.

# Procedural Step Model PROBLEM NO. 28

**Scoring Guide** PSM.28(5)

Student ____________________

Date ____________________

Score ____________________

## A. Experimental Design

The teacher must evaluate and approve the experimental design **before** the student starts the laboratory work.

**Procedure:**

## B. Observations

**Procedural Step Model**

## C. Calculations and Answers

## D. Alternate Solution(s) - Procedure

1. ______________ 6. ______________
2. ______________ 7. ______________
3. ______________ 8. ______________
4. ______________ 9. ______________
5. ______________

---

## For Teacher's Use Only

**Alternate Solution(s)**

Please enter the number of marks (maximum of 5) awarded to the student for an Alternate Solution.

☐ 5

**Experimental Design (15 marks)**

(Please indicate with a check mark the **procedural steps** designed correctly and the **procedural steps** given to the student)

| Steps Designed Correctly | | Steps Given to the Student |
|---|---|---|
| **Phase I** | **Phase II** | |
| 1. ______ | 1. ______ | 1. ______ |
| 2. ______ | 2. ______ | 2. ______ |
| 3. ______ | 3. ______ | 3. ______ |
| 4. ______ | 4. ______ | 4. ______ |
| 5. ______ | 5. ______ | 5. ______ |

**Performance (10 marks)**

(Please enter the appropriate mark in Space III)

Marks are awarded on the basis of the % error in the experimental data.

Experimental Error

| | | |
|---|---|---|
| >30% | ______ | 0 |
| 20-30% | ______ | 2 |
| 10-20% | ______ | 3 |
| <10% | ______ | 4 |

Calculations

a) Step 1 ______ 1

b) Step 2 ______ 1

c) Step 3 ______ 1

Identification of the metal ______ 3

**Experimental Design**

**Phase I**
**No. of steps x 3**

○ I

**Phase II**
**No. of steps x 2**

○ II

**Performance**

○ III

---

**Total Score** ○ I + ○ II + ○ III = ⬡ TOTAL